Diseases of POTATOES SUGAR BEET and LEGUMES

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W. A. R. DILLON WESTON
Illustrated by ANN MURRAY

DISEASES OF POTATOES, SUGAR BEET AND LEGUMES

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DISEASES OF POTATOES, SUGAR BEET AND LEGUMES

by

W. A. R. DILLON WESTON

M.A., Ph.D., Dip. Agric. (Cantab)

Formerly Advisory Plant Pathologist
The School of Agriculture, Cambridge

Illustrations by

ANN MURRAY, B.A.

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PREFACE

In past years the author contributed monthly articles to *Agriculture* on the diseases of farm crops. These gave as simply as possible, and in the form of "life cycles", the more important stages in the life of organisms causing plant diseases, and showed how they could be prevented. The articles, illustrated by his colleague Miss A. Murray, were complete in themselves, but they formed no connected whole and were not readily available for reference. It was thought, therefore, that a useful purpose might be served if they were combined with other material to form a series of short volumes dealing with the chief diseases of agricultural and horticultural crops.

The author thanks the Ministry of Agriculture and Fisheries for allowing him to use material that he published in *Agriculture*, and he records that he has freely consulted their many admirable Bulletins and Advisory Leaflets; and these he recommends to students and to farmers for further reading.

W. A. R. DILLON WESTON,
Cambridge, 1947

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CHAPTER I

THE POTATO AND PLENTY

THE unfolding chronicle of the ages is patterned by the wars that man has waged against his own kind, and the catalogue of his battles forms an imposing index to history. Each successive era has shown its ingenuity in devising better agents of destruction, so that now cities may be laid in ruins and populations annihilated in a few seconds. It might well appear that mankind has become the master of his own destruction.

This is a conceit common after devastating wars, and a correct perspective is not seen until some deadly plague appears to remind mankind that his true enemy is disease. In this connection the story of the potato is of much interest, and a brief account of it is given.

The potato is indigenous to countries on the western seaboard of South America, where there are many wild species in addition to the cultivated kinds. Although not known to Europeans until the Spanish conquest of the New World, it had been cultivated by the Indians of Cuzco and Lake Titicaca since the second century A.D., and probably much earlier. From these centres it spread northwards and southwards along the Andes, and some varieties reached as far south as South Chile. There is some doubt as to when, and by whom, it was first brought to Europe, but it is definitely known that there were two separate introductions. The first was to Spain, about 1570, when it was probably carried as ships' stores; and the second, between 1581 and 1596, when it was brought to England. The history of the potato, its early home and introduction to Europe, is a fascinating story, but one of much complexity, and the reader who wishes to study it is referred to more detailed accounts.[1] He should note, however, that potatoes were not first introduced into

[1] "The Potato in its Early Home and its Introduction into Europe": *Journal of the Royal Horticultural Society*, 1937: 62. "The Story of the Potato", by J. G. Hawkes: *Discovery*, February 1945.

England from Virginia, as is often stated, for no potatoes, either wild or cultivated, were known there until 1621.

For many years after its introduction into England the plant was considered as a botanical curiosity and no serious attempt was made at cultivation; it was not until

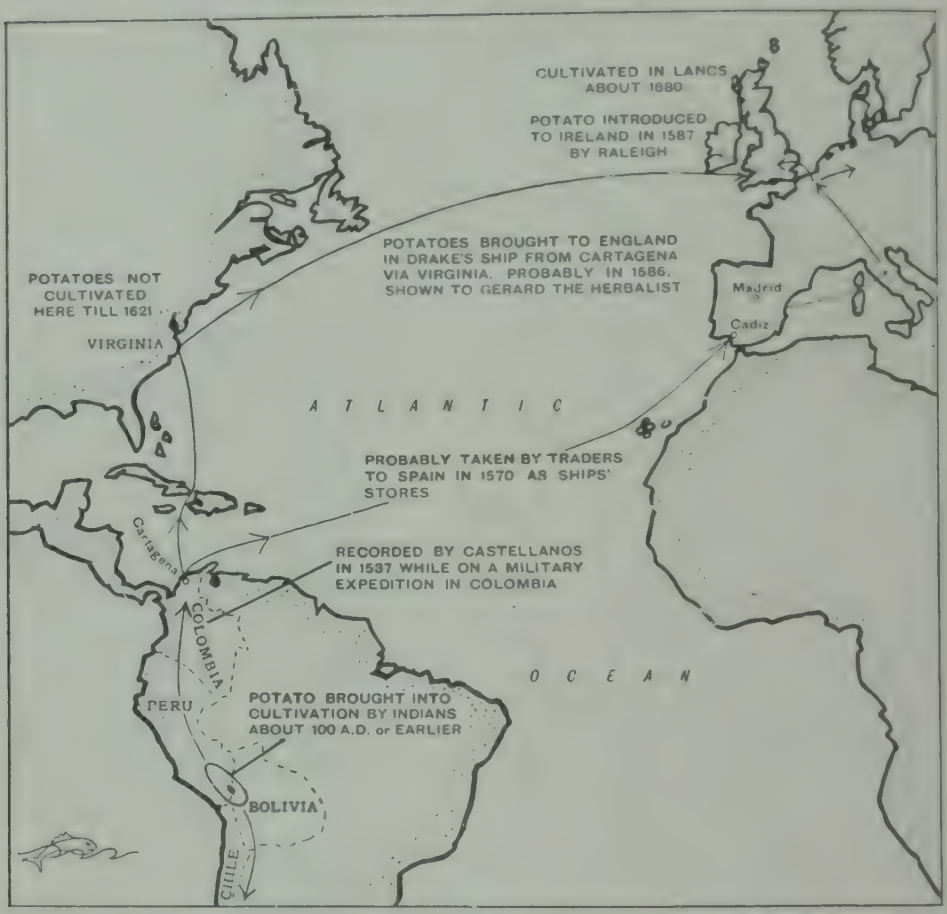

CULTIVATED IN LANCS ABOUT 1680
POTATO INTRODUCED TO IRELAND IN 1587 BY RALEIGH
POTATOES BROUGHT TO ENGLAND IN DRAKE'S SHIP FROM CARTAGENA VIA VIRGINIA. PROBABLY IN 1586. SHOWN TO GERARD THE HERBALIST
POTATOES NOT CULTIVATED HERE TILL 1621
VIRGINIA
Madrid
Cadiz
ATLANTIC
PROBABLY TAKEN BY TRADERS TO SPAIN IN 1570 AS SHIPS' STORES
Cartagena
RECORDED BY CASTELLANOS IN 1537 WHILE ON A MILITARY EXPEDITION IN COLOMBIA
COLOMBIA
OCEAN
PERU
POTATO BROUGHT INTO CULTIVATION BY INDIANS ABOUT 100 A.D. or EARLIER
BOLIVIA
CHILE

FIG. 1. THE INTRODUCTION OF THE POTATO INTO EUROPE

the end of the seventeenth century, when it was introduced into Lancashire from Ireland, that its cultivation became more popular. From Lancashire it gradually spread to other counties in England, but it seems to have found little favour in Scotland and it was not cultivated there until 1683, and did not reach the Highlands until 1743. In Ireland, however, where it is reputed to have been introduced by Sir Walter Raleigh in 1587, it was readily accepted and by 1640 its culture had spread through most of Munster, until by the end of the century

it had become the staple food of the impoverished peasantry. The English might prefer their wheaten bread and bacon, and the Scottish their oatmeal cakes and porridge, but the potato (and a little milk when obtainable) was the main sustenance of the Irish peasant. The political, economic, social and religious injustices which made this so cannot be discussed here, but it is necessary that the reader should have some insight into the mode of life of the Irish peasant in the eighteenth century, otherwise he will be unable to appreciate the significance of future events. In 1776 and subsequently, Arthur Young, one of our greatest pioneers in Agriculture, visited Ireland to study its farming practice and the life of the people. In 1780 he published a book of the greatest interest, *A Tour in Ireland*, and from it the following passages[1] are quoted:

Relative to the cottar system wherever it is found, it may be observed that the recompence for labour is the means of living. *In England these are dispensed in money, but in Ireland in land or commodities. . . . The crop of potatoes, and the milk of the cow, are more regular in Ireland than the* price *at which the Englishman buys his food. In England complaints rise even to riots when the rates of provisions are high; but in Ireland the poor have nothing to do with prices, they depend not upon prices, but crops of a vegetable very regular in its produce. . . . The food of the common Irish, potatoes and milk, have been produced more than once as an instance of the extreme poverty of the country, but this I believe is an opinion embraced with more alacrity than reflection. I have heard it stigmatized as being unhealthy. . . . When I see the people of a country, in spite of political oppression, with well-formed vigorous bodies, and their cottages swarming with children; when I see their men athletic, and their women beautiful, I know not how to believe them subsisting on an unwholesome food. . . . If anyone doubts the comparative plenty, which attends the board of a poor native of England and Ireland, let him attend*

[1] *A Tour in Ireland*, Arthur Young, Vol. II, pp. 112–19 London, 1780.

to their meals: the sparingness with which our labourer eats his bread and cheese is well known; mark the Irishman's potatoe bowl placed on the floor, the whole family upon their hams around it, devouring a quantity almost incredible, the beggar seating himself to it with a hearty welcome, the pig taking his share as readily as the wife, the cocks, hens, turkies, geese, the cur, the cat, and perhaps the cow—and all partaking of the same dish. No man can often have been a witness of it without being convinced of the plenty; and I would add the cheerfulness that attends it.

And so it was that the potato averted famine in Ireland —*and then caused it*. For two and a half centuries it had been grown and then, in 1845, an uninvited and an unexpected guest entered to take his share of the potato bowl. The peasant and his wife, and all that was theirs, made way for a most unwelcome visitor, the causal agent of a most mysterious disease.

CHAPTER II

THE POTATO AND FAMINE

UNTIL 1845 the European potato crop had not been afflicted with any devastating epidemic, although severe losses were often caused by a mysterious debilitating disorder called the "Curl", and gappy crops often resulted from "Dry Rot"—a disease characterized by a hardening of the tissues of the potato sets. These diseases, especially the former, were serious enough, but they were not catastrophic. It had been said for many years "that time, or old age, never fails to bring on the curled or shrivelled disorder", for it had been ascribed as an ailment due to an exhaustion or degeneration of the variety as a consequence of its continued propagation by vegetative means. It had not been explained, however, why this trouble was more prevalent in the south of England than in the north. In agricultural works published up to about 1830, there are many references to Curl, but there appears to be no mention of Dry Rot. From then onwards, however, there are frequent references, one of the best accounts being by Martius, in a memoir published at Munich in 1842. It was possible to do much to prevent the losses which this disease caused, for it had been observed that injury was greatest when cut sets were used, especially if the cut surfaces had been allowed to dry out. If whole tubers were planted, or sets prevented from drying out, the losses were much less.

By 1845, therefore, the position was this: there were two important diseases of the potato crop, Curl and Dry Rot, but neither as yet had inflicted any mortal blow.

In 1845, or a year or so earlier, a new disease appeared in serious form—the "Potato Murrain". Anxiety gave way to alarm. A warning note was sounded.

August 11th, 1845.

To: *The Right Hon. Sir James Graham, Whitehall.*

From: *Robert Parker, a potato grower in Kent.*

Sir.—The importance of the following I hope will excuse so humble an individual addressing you. I am fearful of the entire loss, by blight, of the potato crop of this country. Being myself a large grower in Kent (some years of more than 300 acres), where I farm, I am also a salesman in Tooley-street, and have also been largely engaged in the retail trade, consequently am competent to give an opinion. I received a letter from my foreman at Ash, to say the potatoes were blighted, as in September last year; it was then partial in East Kent. I went on Tuesday last, and found the whole of that part of the country infected, not excepting the smallest spot in the cottager's garden. I traced it the whole distance of the Dover line, from Smarden to the Isle of Thanet; on Thursday last I went to Maidstone, and found it had made rapid strides there also; returned by way of Gravesend, found all alike. The same evening I visited the large growths about East and West Ham, in Essex, and its neighbourhood. I made inquiry of the country people: they said there was nothing the matter; but I soon convinced them otherwise. The misfortune is, those that are near their growth are stopped instantly, and I am afraid will not ripen, consequently must rot. The disease is quite a new thing; none of the growers seem to know anything about it, except in East Kent last year; and my reason for making such strict observations is, I was a very serious loser by it. It first appears by black spots on the lower leaves, if an early sort; in about a week it looks as if it had been struck by lightning, as the haulm is turned black and withered, and the potatoes have begun to rot as they did last season, and which I fear will be general. I am given to understand they are so in Holland and Belgium. If it should be so, it will be a shocking calamity for the poor; and feeling apprehensive for the result, if universal, I think it my duty to apprize you of

it, so that you may take such measures to alleviate as you think fit.

I am, Sir, yours respectfully,
Robert Parker.[1]

These fears were well founded. Blight swept through the country. In Ireland the earlies and the second earlies escaped, only the main crop varieties being affected. In the following year, however, it appeared sooner, in the latter part of July, and this time there was no escape. "On August 1st of that calamitous year, 1846, I was startled by hearing a sudden and strange rumour that all the potato fields in the district were blighted." In a country where the bulk of the people were dependent on this one crop, it could mean but one thing—FAMINE. "Everywhere the fields presented a melancholy sight. The next time the face of the whole country was changed; the stalk remained bright green, but the leaves were all scorched black. It was the work of a night."

In England the potato was a useful subsidiary food to flour and bacon, and in Scotland to oatmeal, porridge and broth made of pork and vegetables, but for the majority of the Irish peasantry it was their very means of sustenance, their existence—for a full-grown man consumed some 12 lb. a day. In a few years by starvation and emigration the population of Ireland was reduced by 2,000,000. "By destroying the staple food supply of a human society already very sick from economic causes, it brought about more of death and suffering than any other disaster since the Napoleonic Wars. It was an historic determinant of human affairs, for in 1846 it was the straw that turned the wavering inclination of British high political policy away from self-sufficiency and the protection of home agriculture to Free Trade and the unbounded expansion of commerce. The passage, on June 26, 1846, of the Act which ultimately repealed the Corn Laws was perhaps the most significant single event in the history of the British Empire."[2]

What was the cause of Blight? The opening paragraph of a prize essay, dated December 11, 1846, and

[1] From *The Farmer's Magazine*, December 1845, p. 545.
[2] *The Advance of the Fungi*, pp. 39–40, by E. C. Large, Jonathan Cape.

published in the *Journal of the Royal Agricultural Society* well illustrates the feeling of frustration that the problem of this malady presented:

> *Of the innumerable hostile agents with which the cultivator of the soil has to contend, some he is able to keep in check by the ordinary course of husbandry; others have from time to time engaged the attention of men eminent in various departments of science. Still there is a mischief in the field, the origin of which is not yet "dreamt of in our philosophy". . . . But probably few subjects of the kind ever presented greater difficulties, its cause being imperceptible, its attack inevitable, its remedy apparently impossible.*

From the highest to the lowest in the land all debated this mysterious malady which had so quickly converted the fresh green haulm into a blackened waste and rottenness. With impressive reasoning, or so it then seemed, philosophers, botanists, chemists and medical men expounded their views. Thunder and lightning, torrential rain, and fog were held by some to be to blame; others thought it due to the degeneration of the potato itself or to the use of forcing manures; whilst a few, the more observant who had noticed a mould growing on the decaying haulm, wondered if it might be due to minute fungi.

A writer to the *Medical Times* of October 18, 1845, says:

> *. . . To close this part of our subject, for we shall take occasion to complete it finally in another article, we give it as our decided opinion that "potato disease" and "potato-murrain" are merely idle terms that bear no relationship whatever to existent things. There is no "disease", no "murrain", properly so-called; the potatoes are just* rotten, *and that is the long and short of it. The discoloration, commencing in this spot and extending to that, the softness, the waxiness, the fetor —all these things, and many more such like, we have seen a score time in potatoes that have spontaneously rotted in a damp dark cellar. We can confirm what the microscopists and chemists say about the appearances and reactions, and tell them plenty of untold truths besides. But not potatoes only any vegetable*

of similar composition will give like results when in a state of decay. These acids, alkalis, atonic defects, sporules, granules, ruptured cells, dust, dirt, etc., are a consequence *of the potato mischief, and not a* cause *of it. . . . Take our word for it, there is no mystery in the affair; cloudy skies and drenching rain have done it all!*

Within two or three years, however, only two theories were tenable—the Fungal theory, and the theory that the disease was due to a vicious mode of cultivation pursued through many years. Until this time it was generally held that the moulds and mildews occurring on decaying vegetation were the result of disease and not the cause of it. Here then was a test case. Was the fungus mould which was found on the decaying potato haulm the cause of the disease or not? The Rev. M. J. Berkeley, perhaps the greatest British pioneer in the whole field of plant pathology, investigated the nature of the disease. He considered that the mould was the cause of the decay, and by his detailed observations did much to prove it.

Men, women and children had died of starvation in their tens of thousands, the tragic years 1845-7 had faded into history, but a new era had dawned and the way was paved for the germ theory of disease. The Rev. M. J. Berkeley was right: a microscopic fungus, *Phytophthora infestans*, was the cause of potato blight. "That little fungus, only to be fairly seen in the strangely lighted field of the microscope, with its filamentous spawn and its translucent spores, not only brought famine to Ireland and unlocked the doors of England's Golden Age; it shed new light on the nature of Disease, awakened the natural philosophers to the significance of those living things that God created small, and called into being a new branch of applied science, second only in importance to medicine and human physiology—the science which was to have for its province the defence of the health of the crops."[1]

The wheel has turned full cycle, a century has passed, two world wars have slain their millions, but *Phytophthora infestans* is still as destructive now as it was in 1846—unless precautions are taken to prevent it.

[1] *The Advance of the Fungi*, pp. 39-40, by E. C. Large, Jonathan Cape. London, 1940.

CHAPTER III

POTATO DISEASES AND THEIR PREVENTION

BLIGHT, LEAF ROLL AND DRY ROT

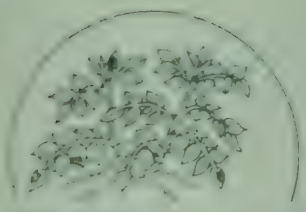
WHAT progress has science made in devising measures to prevent Blight, "Curl" and Dry Rot, the three diseases familiar to potato-growers a hundred years ago? The successful control of any plant disease depends upon a clear understanding of its cause, and it is not until this becomes known that remedial measures are possible.

BLIGHT

Blight, the disease caused by the fungus *Phytophthora infestans*, is very dependent upon the weather. In a dry season it is local in its occurrence and causes little damage, but when warm moist periods are frequent during the summer, it spreads rapidly and severe attacks may occur. The disease appears first in south and south-west England and Wales, but it does not become a menace there, or elsewhere, unless moist muggy conditions prevail. It has been suggested from time to time that Blight, once it appears, sweeps up from the south or the south-west to eastern and northern parts, but there is no reliable evidence of this. The disease, in a latent form, is present on most farms, but it does not assume epidemic proportions unless weather conditions are such that they favour the propagation and dispersal of the "seeds" of the disease—the spores of the fungus. In the south and the south-west these conditions occur at an earlier date than they do elsewhere, and consequently the disease, in serious form, usually appears there first.

How does Blight start? It develops on shoots produced from blighted tubers left in the field the previous autumn or thrown away when the clamp is opened. It may also start from blighted tubers planted among healthy ones. Not all of these, however, produce diseased shoots. Many

1

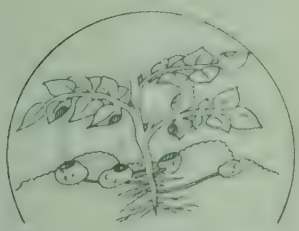


The spores are splashed on to healthy plants which are in turn infected—

2

Blight spreads across the healthy crop

3

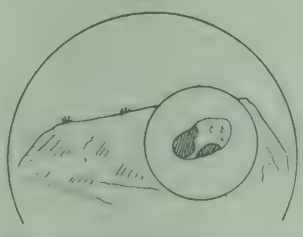


The spores are washed down from infected leaves to badly earthed-up tubers.

4

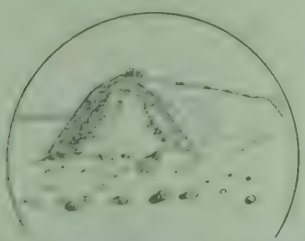
If the crop is lifted in wet weather the tubers become infected from contact with diseased haulm.

5



The infected tubers develop blight in the clamp

6

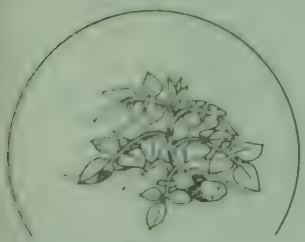


The clamp is opened and the diseased tubers thrown out

7

A diseased tuber left in the field on the site of an old clamp may produce an infected shoot.

8



An infected "volunteer" plant.

9

The underside of an infected leaf with the blight fungus much enlarged.

THE LIFE CYCLE OF *PHYTOPHTHORA INFESTANS* — THE POTATO BLIGHT FUNGUS

FIG. 2. THE POTATO BLIGHT FUNGUS

shoots from affected tubers escape infection; and severely blighted tubers often rot in the ground without sprouting. There is nothing mysterious in the onset of Blight: it originates from *blighted* tubers and these are the sources of infection. If weather conditions favour the development of the fungus, it increases rapidly and Blight becomes epidemic, but if unfavourable conditions prevail the disease is checked.

The first symptoms of Blight are dark brown or olive-black water-sodden patches on the leaflets, on the under-surface of which, around the margin of the diseased areas, a white mould appears. This is the fungus *Phytophthora infestans*, the cause of Potato Blight. The fine white strands are minute branched stalks bearing spore bags, and these, in moist warm weather, are produced in enormous quantities. When the spore bags fall on to leaves wetted by rain or dew they release a number of motile spores, each capable of causing infection. These swimming spores soon germinate and each sends out a minute germ-tube which pushes its way through the epidemis of the leaf. Once inside, the spawn ramifies in and among the cells, and absorbs its nourishment from them—the invaded cells die, and the leaves become black and rotten. Hot dry weather, however, is unfavourable for the fungus, for without water the spores cannot germinate.

How is Blight prevented? The neglected sites of old potato clamps are a fertile source of disease. Every farmer *must* appreciate this if he is to reduce the losses which Blight causes. A self-set plant, a "volunteer" or "groundkeeper" as it is sometimes called, is a source of disease. Not only may it harbour Blight but also virus infection and eelworm. . On a well-managed farm self-sown plants should not occur. How can they be prevented? First, tubers should not be left on the field to give rise to "volunteer" plants. As neither the plough nor the spinner will deal *completely* with the harvesting of the crop, the harrows should be run over the picked portion of the field at the end of each day, and the exposed tubers collected. The field should then be dragged with the cultivator, and any more tubers brought up should be collected and clamped separately with the

harrowings. Second, when the clamp is opened diseased tubers should not be thrown out and left lying about to harbour disease. They should be collected, carefully sorted out and, whenever possible, the best of them boiled and used for pig feeding. The remainder should be burnt (not an easy matter) or else thrown into a pit, trampled down, and covered with a deep layer of soil. Time and again the first outbreaks of potato Blight have been found

FIG. 3. SECTION OF TWO POTATO RIDGES
(A) Tubers protected from blight.
(B) Tubers not protected from blight.

near the sites of old potato clamps or of rubbish heaps on which diseased tubers have been dumped. It is from such plague spots as these that Blight so often spreads, especially if it is near a potato crop grown in a sheltered position or when the air is moist and stagnant. As Blight may start from planting blighted tubers, every reasonable precaution should be taken to avoid diseased seed. It is an axiom of sound farming practice always to start with healthy stocks, and the potato is no exception. *Plant clean seed which is virus-free, or relatively so, and discard all tubers showing Blight or Dry Rot.* Wherever possible seed should be boxed, periodically examined, and diseased tubers destroyed.

The "seed" has been sown. What further precautions are necessary? The haulm and the tuber must be

safeguarded against chance infection, for once Blight starts, it quickly spreads. If the weather is warm and moist each leaf produces millions of spores, and these are splashed or driven by the rain farther afield.

Protecting the Tubers.—Many farmers believe that once Blight gains a hold on the foliage, it works down the stems into the tubers. This is a fallacy. The tubers become infected from spores that are washed down from the haulm during rainstorms and are carried for short distances through cracks in the soil. If the tubers are exposed, or very near the surface of the soil, the spores come into contact with them and infection results. Can this be prevented? Blight spores are delicate and short-lived, and the better the earthing-up the smaller the chance they will have of reaching the tubers. Plenty of soil and compactness at the sides and top of the drills should be the aim. The ideal is a bulky, crested ridge; the thing to avoid, a shallow, split-topped covering. A good ridge that reduces the chances of greening to the minimum will likewise reduce Blight.

Protecting the Haulm.—Spraying the crop with Bordeaux or Burgundy mixture, or proprietary copper preparations sold in the form of powders or pastes ready for mixing with water, will protect the haulm for a limited period. To be most effective spraying must be done before, or as soon as, Blight spots are seen on the foliage. For maincrop varieties two applications are necessary, and in very wet warm seasons a third may be required; the first should be given before the plants meet in the rows, and the second about three weeks later. Earlies do not usually require spraying. In some areas, however, there are practical difficulties in applying sprays, and the crop is dusted with copper powders. Dusting is not so effective as spraying, and where dusts are used four, five, or more applications are made at fortnightly intervals, beginning before the plants are earthed up. It is always wise, however, to seek local advice before planning a spray programme because the time at which Blight appears, and its severity, is not the same in all parts of the country. The disease occurs first, and is most severe, in southern and coastal districts, and here spraying or dusting is a

valuable safeguard. In midland and northern districts it appears later and is often less severe, so that in these parts, if other precautions are taken, spraying may not be necessary. Where Blight starts early, however, or in those areas where the crop is very prone to attack—such as low-lying fields or those in sheltered positions where the air is stagnant—the spraying of maincrop varieties should be a routine measure. Spraying or dusting should not be done in the immediate vicinity of large industrial areas as the haulm may be scorched owing to reactions between the spray deposits and acid fumes in the atmosphere.

Blight in the Clamp.—Why is it, in spite of the precautions of earthing up and spraying, that blighted tubers are found in the clamp? Good moulding up prevents Blight only while the tubers are still safely protected in the soil. When lifted, however, they are subject to infection from any Blight spores which may be present. Spraying the crop effectively safeguards the haulm for several weeks during a vital period and often considerably increases yield. But Blight often appears even on sprayed foliage towards the end of the season and, if the crop is lifted too soon, spores from the foliage may infect the exposed tubers. Many farmers believe that Blight spreads from tuber to tuber in the clamp, but there is no appreciable spread by contact, although certain forms of wet and dry rot may develop in this way, especially if the clamp is badly made. When Blight develops in a clamp the reason is that the tubers, although they appeared clean at lifting time, carried Blight spores on their surface. The tubers are contaminated *before* they are clamped and, if their skins are wet, subsequent infection of the flesh takes place. What is the remedy?

Blight spores are delicate and short-lived, and they require moisture before they are able to cause infection. Whenever possible, therefore, lifting, carting and clamping should be done in dry weather. If lifting can be delayed until the tops have been quite dead for at least a fortnight, the risk of infection is negligible and no special precautions are needed. If the tops remain green very late, however, with Blight spots present on them, they

should be cut off or destroyed ten days or more before the crop is lifted. On small areas of an acre or so it is practicable to cut with a scythe but on large acreages chemical means are employed, usually spraying with a solution of sulphuric acid. Burning off the haulm with sulphuric acid is practised mainly in the northern half of the country, and the work is usually done by spraying contractors, because of the special acid-resisting machines required. Destroying the haulm in this way not only prevents blighted tubers but destroys many weeds and makes the lifting of the crop easier.

If the precautions that have now been outlined were generally adopted, Blight would no longer be a menace to the potato crop—and to man. Unfortunately many farmers are still content to regard it as some mysterious, unavoidable evil, and one which must inevitably run its own course. This is not so for Blight is caused by the microscopic fungus *Phytophthora infestans,* and *it can be prevented.*

The outlook for the future is, however, very hopeful, for the plant breeders are trying to produce new varieties resistant to the disease. In recent years several large-scale surveys have been made by scientific expeditions to study the potato in its natural habitat and to collect representative varieties of wild and cultivated species. The information obtained, and the material collected, have been of the greatest help to plant breeders in their efforts to breed resistant varieties which would be profitable to cultivate on a commerical scale.

LEAF ROLL

The "Curl", or Leaf Roll as it is now called, was known about a hundred years before Blight appeared in this country, and towards the end of the eighteenth century, when the cultivation of a greater acreage of potatoes was advocated, it was the subject of much speculation, prizes being offered for the discovery of some means of arresting its progress. In the spring of 1795 the President of the Board of Agriculture, fearing a scarcity of grain and possibly famine, appointed a committee "to extract information from the county reports and other authorities

1

This insect, by transmitting a virus, causes the degeneration of potato stocks

8

If used for seed they will produce a low yielding crop.

2

Here are two potato crops, one is healthy, the other affected with virus disease.

7

Although tubers from such a plant appear healthy they are "poisoned" by the virus.

LEAF ROLL

A

POTATO VIRUS DISEASE

—

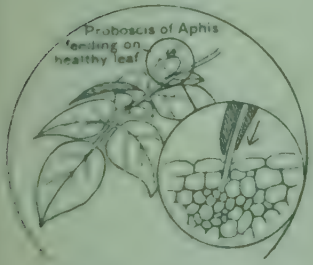
Avoid it by using

CERTIFIED SEED

3

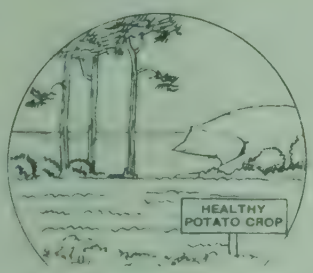
This plant from the diseased crop has Leaf Roll Virus.

6



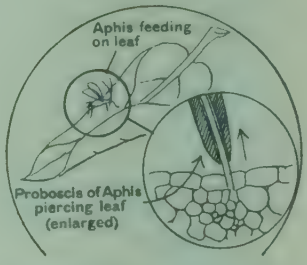
. . . They will feed on the healthy leaves and inject the virus back into the leaves.

5



Should these aphids reach a crop grown from virus-free seed . . .

4



When the aphids feed on these plants they suck up the virus-infected sap.

FIG. 4. LEAF ROLL OF POTATOES

concerning the culture and use of potatoes". This was done and in the summer of that year the report was published,[1] one chapter being devoted to the distemper then known as the "Curl". This chapter starts as follows: "In the North Riding of York, they procure their seed from the Moorlands, or from Scotland, to avoid the curl: the first year, free; the second, some curled; the third almost all. . . . It is singular that the distemper of the curl is unknown in the higher district of West Lothian, at an altitude of about 400 feet above the level of the sea: brought from that district, they continue sound for two years; but afterwards become curled." The various authorities who were consulted in this early investigation gave diverse and conflicting views to account for the distemper. Some thought it arose from the use of over-ripe tubers, others from under-ripe; some maintained it was due to growing the same sorts too long on the same land, whilst others believed it was brought about by the nature of the soil.

Some fifty or so years later it was considered that the best protection would be to select seed from crops free from the Curl and to "get sets from more barren districts, to plant in the richer and more hazardous bottoms". Another fifty years were to elapse, however, before the cause was found, for it was not until after the First World War that the mystery was solved. It is now known that the "Curl", or Leaf Roll, is a *virus disease*. The causal agent is an infectious principle in the sap of "curled" plants, but this (unlike bacteria and the spores of parasitic fungi) cannot be seen by means of the ordinary microscope. The virus of Leaf Roll is transmitted from diseased to healthy plants by aphids (greenfly), and the important carrier or "vector" is the aphis *Myzus persicae*. When this insect feeds upon a plant affected with Leaf Roll it sucks up some of the virus with the sap, which is later injected into the tissue of the healthy plant. In this previously healthy tissue the virus multiplies and is carried in the sap throughout the plant and to the new tubers. As the potato is propagated vegetatively, it follows that once a potato

[1] *Report of the Committee of the Board of Agriculture, concerning the Culture and Use of Potatoes*, 1795.

plant is infected with a virus, the plants arising from it will be affected similarly.

Symptoms of Leaf Roll.—Healthy plants infected early in the season show "primary leaf roll", which is seen as a rolling of the leaflets of the upper leaves. If infection occurs rather late, however, no symptoms appear, and it is not until the second and subsequent seasons, *when infected seed is planted*, that obvious signs of the disease are seen. Then, soon after the plants are up, the margins of the leaflets of the lower leaves roll upwards and inwards, and, as the plant grows, this rolling extends to the upper leaves so that eventually all the leaves have a rolled appearance. Apart from these symptoms, however, plants affected with Leaf Roll are usually stunted, and with leaves harsh and leathery to the touch.

Measures of Prevention.—Seed can be produced from certain districts in Scotland, Ireland and hill districts of England and Wales which is almost free from virus diseases, but when grown in the east or south of England the virus infection increases steadily; after stocks have been grown for one or two years in these parts of the country it is usually necessary to obtain fresh seed. The relative freedom from virus of the seed grown in the seed-producing districts mentioned above is due to the fact that the aphis responsible for the spread of the disease does not flourish there and consequently the virus is transmitted only to a limited extent. As diseased plants are systematically rogued in these seed-growing areas, it follows that the health of the crop can be maintained at a very high level. It is clear therefore that a farmer can and should avoid Leaf Roll—and other potato virus diseases, such as Rugose Mosaic (*Severe Mosaic*) and Mottle (*Mild Mosaic*) by purchasing seed as free as possible from virus diseases.

Certified Seed.—To promote the improvement of stocks in seed-growing areas, and to assist growers wishing to purchase reliable stocks, the Agricultural Departments for England and Wales, Scotland and Northern Ireland operate schemes for the inspection and certification of crops grown for seed. All growers are advised to purchase only certified seed. The following classes of health certificates are now issued:

"S.S." (STOCK SEED) CERTIFICATE for crops 99.95 per cent true to type and which contain not more than 0.25 per cent of virus diseases and wildings, including not more than four plants per acre affected with severe virus diseases and wildings. Stock Seed is the highest grade of seed, specially suitable for the production of seed potatoes in recognized seed-growing areas.

"A" CERTIFICATE for seed from crops 99.5 per cent true to type and which contain not more than 1 per cent of readily visible virus diseases and wildings, of which not more than 0.5 per cent may be Leaf Roll, Rugose Mosaic and wildings. Seed with an "A" certificate may be regarded as the best grade for commercial ware production.

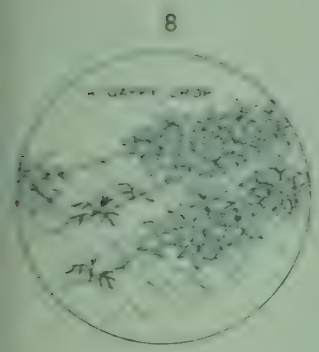
"H" CERTIFICATE for seed from crops 99.5 per cent true to type, and which contain not more than 3 per cent of the diseases Leaf Roll and Rugose Mosaic, and of wildings.

DRY ROT

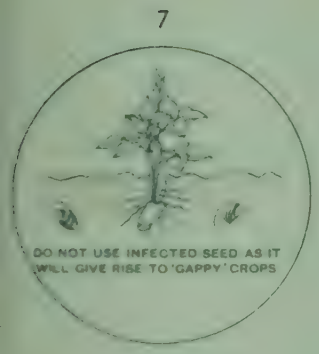
Dry Rot was known in Europe before the advent of Blight, for Martius in 1842 described the disease and noted that the condition was associated with the presence of a fungus.

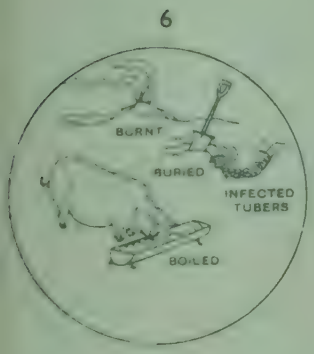
Dry Rot is due to the fungus *Fusarium,* notably *F. caeruleum,* and in winter and spring causes a rot of stored tubers, especially early sorts and some maincrop varieties. There is still doubt as to the time and mode of infection but most of it probably takes place at digging time, the fungus gaining entry through wounds and bruises, but it may also occur if tubers are damaged in transit or roughly handled. For some time after infection there is little to show that the disease is present, and it is not until the early months of the year, when the tuber is nearer to the time of sprouting, that the typical symptoms become very apparent.

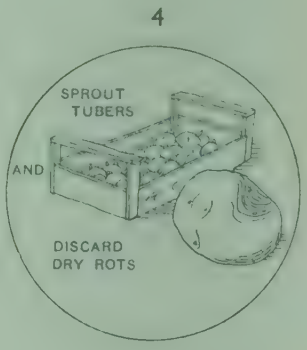
Symptoms of Dry Rot.—A brown patch appears on the skin, this increases in size, and becomes flattened and slightly sunken. As the affected part becomes gorged with spawn, the skin crinkles into concentric rings and white cushion-shaped tufts appear on the surface. This is the spore-bearing stage of the fungus, and each white tuft is



Dry Rot of potatoes is a storage disease caused by *Fusarium caeruleum*. The earlies suffer most but some maincrop varieties are affected. The fungus gains entry through wounds made at lifting time (1 and 2) or later if they are roughly handled and badly bruised (3). Whenever possible susceptible varieties should be boxed in sprouting trays (4), periodically examined (5), and diseased tubers destroyed (6). If seed showing Dry Rot is used the crop will be "gappy" (7 and 8).







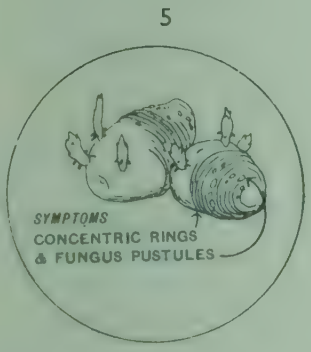


FIG. 5. DRY ROT OF POTATOES

a pustule bearing innumerable spores—the "seeds" of the disease. As Dry Rot gains a hold, the shrinkage increases, cavities appear in the flesh, and finally the tubers become hard and dry.

Susceptibility of Varieties. Early varieties are very susceptible to Dry Rot, but the severity of the attack varies with the season; in some years the losses are very high but in others much less. May Queen, Ninetyfold, Arran Pilot, Catriona and Di Vernon are all very susceptible, but Sharpe's Express, Edzell Blue and Duke of York also suffer severely. Of the maincrop varieties Doon Star is often badly affected and much loss is incurred. In some seasons it is also prevalent in clamps of Majestic and Redskin.

CONTROL MEASURES. *Great care should be taken at lifting time in digging seed potatoes, especially early varieties.* Wounds, bruises, and abrasions admit the fungus, and consequently these must be avoided if infection is to be prevented.

Rough handling and excessive bruising of the seed during transit from merchant to farmer should also be reduced as much as possible. The seed of susceptible sorts should be ordered early, and when received should be boxed, and well exposed to light. The trays should be periodically examined and all diseased tubers showing Dry Rot or Blight should be removed. They should not be tossed to one side and left to contaminate houses and stores, or become plague spots in the field. They should be destroyed: those less badly affected can be boiled and used for pig or poultry feeding, but the remainder should be burnt or buried.

When bad attacks have occurred the sprouting boxes, and the interior of the store, should be washed down with a 2 per cent solution of copper sulphate (2 lb. in 10 gallons of water) before they are again used for storing potatoes.

Can seed tubers be treated with disinfectants to prevent disease? Experiments have shown that this can be done provided they are treated *immediately after lifting*. Good control of Dry Rot has been obtained by dipping seed for about 15 seconds in a 1 per cent solution of

formalin. Satisfactory control has also followed the use of certain organo-mercury preparations, and these have a residual protective effect not obtained with formalin. These mercurial dips, however, are proprietary articles and must be used according to the makers' instructions. A more recent development is the use of non-mercurial preparations that are dusted on the seed when lifted.

Tubers showing Dry Rot should *not* be planted otherwise a gappy crop will result. It is seldom profitable to attempt to cut out sets from diseased tubers.

CHAPTER IV

GAPPY POTATO CROPS

ISOLATED "misses" in a potato crop may seem trivial and of small account, but "many a little makes a mickle". What are the main causes of "gaps" in the potato crop? Apart from depredations by insect pests, such as wireworms, the chief causes are parasitic fungi; and of these *Fusarium caeruleum*, the cause of Dry Rot, has already been mentioned.

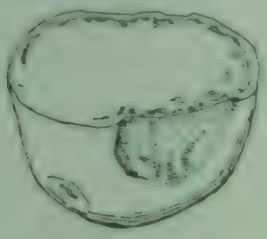
Tubers badly affected with Blight may also fail to sprout, or the shoots die, but this is the best thing that could happen to them for otherwise blighted shoots might be produced which would serve as a source of Blight infection for neighbouring plants.

Apart from Dry Rot and Blight, however, there are two diseases which are frequently responsible for "gappy" crops, and a short account of them is now given.

BLACK SCURF AND STEM CANKER

Symptoms of Black Scurf.—This disease is due to *Corticium Solani,* and it may either kill the shoots or, by causing a stem canker, check plant growth. On the surface of affected tubers are dark brown bodies which look rather like crusts or pads of dirt, and they are often mistaken for this. They are not dirt, however, for if the tubers are well washed they will still adhere, although they can be readily detached by scraping with the fingernail. The general appearance of the fungus in this stage has given rise to the name Black Scurf. If one of the pads is removed and examined under the microscope it is seen to consist of tightly woven strands of spawn. These fungus pads, or *sclerotia* as they are called, are resting bodies and they enable the fungus to overwinter. As they are entirely superficial they do not harm the tuber, and there is no penetration into the flesh. When the tubers are planted, however, the fungus becomes active and the spawn invades the young shoots.

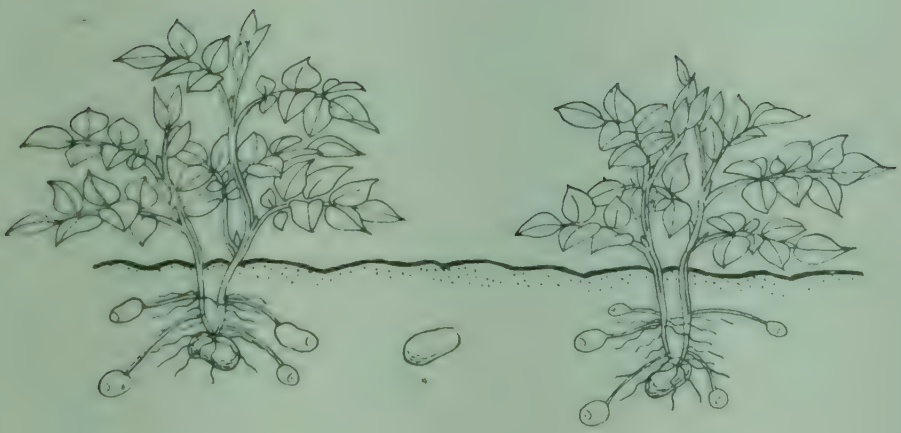
Phytophthora infestans.



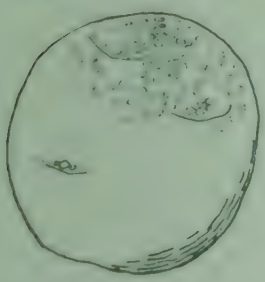
Blight

Fusarium caeruleum.

Dry Rot



Oospora pustulans



Skin spot

Corticium Solani
(Rhizoctonia stage)

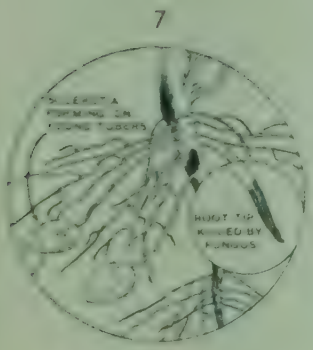
Stem canker

FIG. 6. DISEASES OF POTATOES THAT CAUSE "GAPPY CROPS"

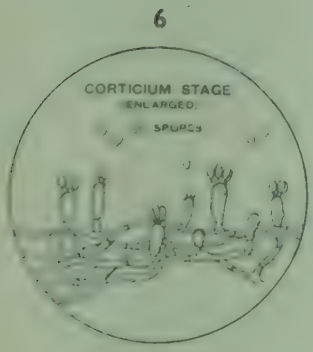
When the attack is severe the tips of the young shoots die and side shoots develop; but they too may be invaded and killed before they appear above the surface of the soil, and a gap results. These symptoms are most pronounced when the weather after planting is cold and wet, especially if the soil is heavy and poorly drained. In this acute form the disease is more prevalent where rotations have been shortened and potatoes grown too frequently, for in these circumstances the disease can be contracted from sclerotia in the soil. Apart from killing the young shoots the fungus also causes a canker of the stem below ground.

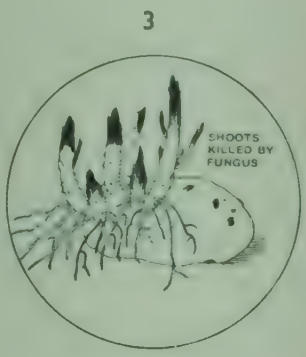
Symptoms of Stem Canker.—If the injury to the underground part of the stem has been extensive, the uppermost leaflets turn slightly yellow, roll up and wilt; but as somewhat similar symptoms appear with other diseases, the parts below ground should always be examined. If the fungus is present, brown streaks or patches will be seen on the stem below soil level and the tips of some of the shoots may be dead. A slight infection of this kind is very common and probably does little harm when the plant is actively growing; but if quick growth is arrested by cold weather and the infected parts increase in size or the stem becomes girdled, then the plant is severely checked and the affected stalks may wilt and die. When the roots are also attacked growth is further impeded, and consequently lower yields result, although the actual "misses" in the crop may be few.

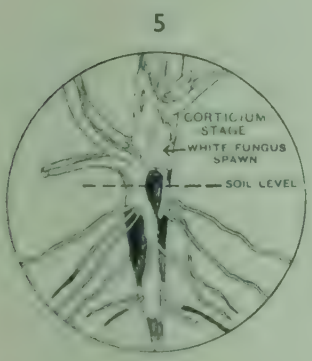
The Life Cycle.—At one time it was thought that the fungus had no sporing stage and it was named *Rhizoctonia Solani*. It is now known, however, that in late June or July the spawn grows upwards to the collar of the plant and produces on the stem at soil level a thin greyish-white felt of spawn which bears spores. This spore-bearing felt had already been noted and was known as *Corticium*, but mycologists did not recognize the connection betwen it and the presence of *Rhizoctonia* under the ground. Since the spores are borne on typical basidia the fungus is now more properly called *Corticium Solani*. The significance of the spores, which are readily dispersed by the wind, is not yet known with any certainty.



The gaps in this potato crop (1) are due to *Corticium Solani*, the fungus causing Black Scurf and Stem Canker. Infection occurs from resting bodies (sclerotia) on the "seed" (2). The fungus may kill the young shoots (3), or check the growth by causing Stem Canker (4). Later, a white felt of spawn forms on the stem at soil-level (5). This is the spore-bearing stage (6). Below ground sclerotia are formed on the tubers (7). Losses from this disease can be reduced by planting *clean seed*.







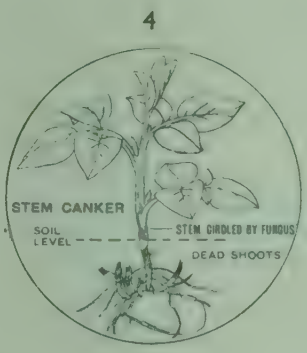


FIG. 7. BLACK SCURF AND STEM CANKER OF POTATOES

The white spawn does not cause any injury because, unlike the brown spawn below ground, it does not penetrate the tissues of the stem.

The course of the disease is as follows. In the form of sclerotia the fungus remains dormant until planting time when it attacks the young shoots and roots, sometimes killing them. It invades the stem below ground, checking growth; and later produces spores at the collar of the plant. Whilst this is happening fresh sclerotia are being formed on the developing tubers.

CONTROL MEASURES. Tubers severely affected with Black Scurf should not be used for seed, and a sound sequence of cropping, in which potatoes are not taken too frequently, should be practised. Poor drainage should be improved.

Losses from Black Scurf, and certain other diseases, would be much reduced if seed potatoes were sprouted in boxes, periodically examined, and diseased tubers discarded.

SKIN SPOT

The causal agent of Skin Spot, a descriptive name given to a disease observed by Pethybridge in western Ireland in 1914, was found by Owen five years later to be a fungus not previously described, and it was named *Oospora pustulans*. Much, however, still remains to be discovered concerning its life cycle and mode of infection.

The fungus penetrates the flesh to only a very slight extent, and there is no appreciable decay. On ware tubers, therefore, it is merely an undesirable surface blemish. On seed tubers, however, it may cause much loss, for the fungus may invade the eyes, kill the buds and so prevent sprouting—with the result that "misses" occur in the crop.

Symptoms of Skin Spot.— The spots, which appear on the surface of the tuber, have the appearance of tiny pimples about the size and shape of a small pin's head. They may be raised or slightly sunken, light or dark in colour, the type of spot depending upon the variety attacked. "In the coarse-skinned varieties such as Golden Wonder definite pimples are developed, which when

wetted become darker brown than the skin. In the smooth-skinned varieties such as Arran Banner, the diseased spots are scarcely raised, but consist of small, dark, circular spots with slightly raised centres, the areas being brown or black in colour."[1] The spots may be scattered singly over the surface of the tuber, or closely packed together.

Mode of Infection.—The mode of infection is not yet fully understood, but it is assumed that the fungus is present in the soil and that the tuber becomes infected at some stage during its growth. The conditions favouring infection are also not clear, but it is thought that it is more likely to occur when soil temperatures are low. The spots are rarely observed on the tubers when they are lifted, but they become evident during storage, and are said to develop more readily on clamped tubers than they do on boxed and sprouted seed.

CONTROL MEASURES. Avoid planting tubers with Skin Spot. Box and sprout seed in dry, light, airy houses and discard "blind" tubers before planting.

[1] *Potato Growing for Seed Purposes*, W. D. Davidson, Irish Free State Stationery Office, Dublin.

CHAPTER V

POTATO SCAB AND WART DISEASE

THE potato suffers from two entirely different kinds of scab and it is sometimes difficult to distinguish them. The more prevalent sort is Common Scab caused by species of *Actinomyces*; the other is Powdery Scab and the parasite responsible is *Spongospora subterranea*.

COMMON SCAB (*Actinomyces spp.*)

Symptoms of Common Scab.—At one time it was supposed that the scabby appearance of potatoes was due to mechanical injury by soil particles or to irritation caused by certain substances in the soil. Lime was often blamed and many farmers still believe it to be the cause. This is not correct, however, for lime, although it may induce conditions favourable for the development of Scab, does not cause it. The disease is due to a fungus which inhabits the soil. It was thought until recently that only *Actinomyces scabies* was responsible, but it is now known that other species are also concerned. Although *Actinomyces* is a normal inhabitant of most cultivated soils, the injury which it causes is greater on some types of soil than on others. It is usually severe on sandy or gravelly land low in organic matter, and on alkaline soils or those made alkaline by heavy applications of lime or the use of unblanced fertilizers. When potatoes are first grown on certain types of reclaimed fenland they are also liable to be badly scabbed, but after the land has been in cultivation for some years the disease becomes less severe. Apart from soil conditions Common Scab is also influenced by the weather, and is usually more prevalent in dry seasons than in wet ones.

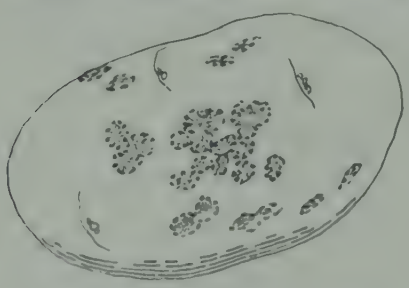


FIG. 8. COMMON SCAB
(*Actinomyces scabies*)

The typical scabby appearance of potatoes results from the formation of loose corky tissue produced by the tuber in an effort to resist the further entry of the fungus. It may assume several forms and this slight variation of appearance has given rise to the use of various names such as superficial Scab, pitted Scab, stud Scab, tumulus Scab, etc. These various forms, however, must not be confused with Corky (Powdery) Scab which is caused by a different parasite.

CONTROL MEASURES. Common Scab is a troublesome disease and, in farming practice, it is often difficult to control. When it is consistently severe, and the land is sandy or gravelly, an attempt should be made to incorporate more fresh organic matter into the soil. This can be done by ploughing in a green crop, such as rye, mustard or vetches. On alkaline soils the use of ammonium sulphate and superphosphate tends to reduce scab infection but lime, soot and alkaline fertilizers aggravate it.

Badly scabbed tubers should not be sown for seed for not only may the eyes be injured and a weak or gappy crop result, but the parasite will be introduced again into its natural habitat. The planting of slightly affected seed in land which has not carried potatoes for many years may sometimes produce badly scabbed tubers. On soils favourable to Scab infection, potatoes should not be grown too frequently, the longer the interval the better.

In recent years beneficial results have been obtained from disinfecting seed tubers before planting, provided that an interval of four or five years has intervened since the previous potato crop. This treatment consists in dipping seed tubers before planting in solutions of certain organo-mercury compounds, these being applied as directed by the maker. This method is still in the experimental stage.

POWDERY SCAB (*Spongospora subterranea*)

Symptoms of Powdery Scab.—This disease was formerly called Corky Scab, but the term Powdery Scab is better because it is more descriptive of the powdery nature

of the spore-balls contained in the scabs. In a mild form it occurs on the surface of the tuber as circular spots of varying size. Only a few isolated scabs may appear, or many, and these may be so closely crowded together that a large area of the surface is affected. For a time the skin over the spots remains intact but later it breaks and a dusty powder is released. This consists of a mass of spore-balls, each of which is composed of many single-celled spores; it is these bodies which contaminate the soil and are responsible for subsequent infection of Powdery Scab. It is often very difficult to distinguish Powdery Scab from

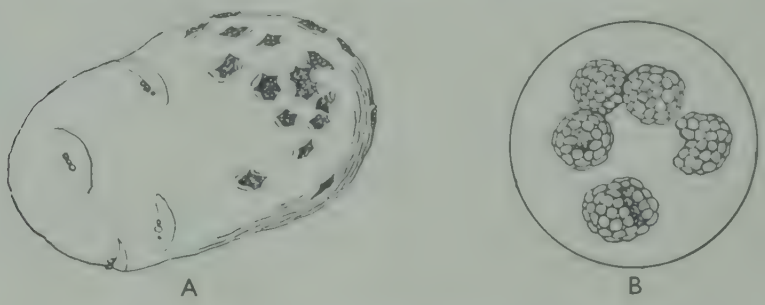


FIG. 9. POWDERY SCAB (*Spongospora subterranea*)
(A) Symptoms on tuber. (B) Spore balls.

Common Scab, especially when most of the spore-balls have been released. In a mild form Powdery Scab is not very important, but sometimes the symptoms are more acute. The surface becomes heavily studded with spots, and these on breaking form deep pock-like marks or cankerous wounds. Sometimes the tuber is malformed, but this distortion can also be brought about by "secondary growth". Occasionally the parasite continues to develop on clamped tubers and gives rise to tumour-like growths. These symptoms may easily be mistaken for Wart Disease, and consequently all abnormal growths of this kind should be submitted to an expert for microscopic examination.

Unlike Common Scab which is more prevalent in dry seasons, Powdery Scab thrives best in wet weather or on badly drained soils. Lime, however, favours both diseases. Powdery Scab is not so widely distributed as Common Scab, and it is relatively of slight economic importance.

CONTROL MEASURES. The appearance of Powdery Scab is often a sign that drainage is poor, and that the land has been cropped too frequently with potatoes. These faults should be remedied.

Potatoes substantially affected with any form of Scab should not be used for seed, and it should be noted that under the Sale of Diseased Plants Orders of 1927 and 1936, potatoes substantially affected with Powdery Scab (*Spongospora subterranea*) may not be sold for planting purposes.

As with other disease organisms which inhabit the soil,

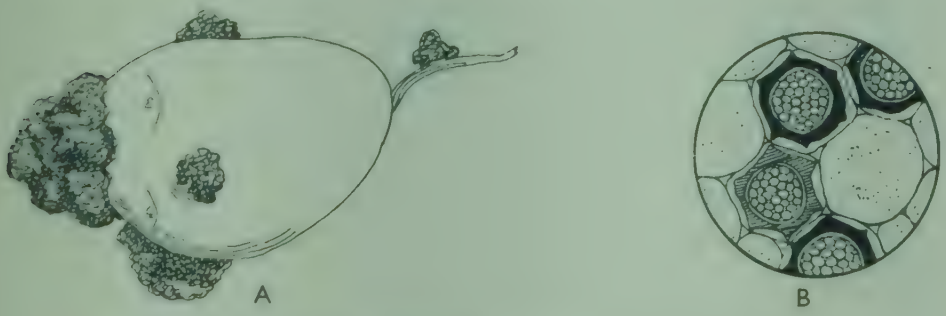


FIG. 10. WART DISEASE (*Synchytrium endobioticum*)
(A) Symptoms on tuber.
(B) Section of "wart" showing resting sporangia.

care should be taken to see that the parasite is not introduced into clean land.

WART DISEASE (*Synchytrium endobioticum*)

Vigilance is always necessary if plant diseases are to be kept in check, for there is no knowing when new troubles may arise. A good example is the appearance of Black Scab, the disease which we now know as Wart Disease. In this country attention was drawn to it in 1900, but it did not cause much concern until about 1907. It was then realized that a serious menace had been steadily accumulating and that the potato crop was again threatened.

The symptoms of Wart Disease are not usually noticed until lifting time when warty, tumour-like growths are seen on the tubers. These are usually situated in the region of the eyes, and they may be small or large masses as big

as the tuber itself. In the early stages of development they are light in colour and not unlike the curd of a cauliflower; indeed the term "cauliflower disease" was one of the earlier names by which the disease was known. With advancing age the "warts" become brown or black and decompose into a putrid mass. Contained in this are the reproductive bodies of the fungus —thick-walled resting *sporangia*. It is these which contaminate the soil and lead to subsequent attacks of Wart Disease.

Fortunately, before Wart Disease had become widely distributed a discovery of the greatest importance was made. It was found that some varieties were not attacked —even when grown on land heavily contaminated by the fungus. The discovery of immune varieties, and the wise legislation which followed, averted disaster. The disease was scheduled under the Destructive Insects and Pests Act, and it became compulsory to notify all outbreaks. Districts where Wart Disease existed were then defined, and within these areas the growing of other than immune varieties was prohibited. From time to time changes have been made in the original legislation relating to this disease, but, although the scheduling of infected areas and the need for "Clean Land" certificates for seed potatoes grown in such areas is now abolished, outbreaks of the disease must still be notified, and only approved immune varieties may be grown on land on which the disease has occurred at any time. These and other measures relating to the control of the disease are given in the Wart Disease of Potatoes Order, 1941, and the following list gives the names of the more commonly grown immune varieties approved by the Ministry of Agriculture and Fisheries for the purpose of this Order.

Early: Arran Pilot, Ballydoon, Di Vernon, Doon Early, Snowdrop (Witch Hill), Ulster Chieftain.

Second Early: Arran Comrade, Arran Luxury, Arran Signet, Ben Lomond, Catriona, Dunbar Rover, Edzell Blue, Great Scot.

Early Maincrop: Arran Banner, Arran Peak, Doon Star, Gladstone, Majestic, Redskin.

Late Maincrop: Arran Consul, Arran Victory, Dunbar Standard, Golden Wonder, Kerr's Pink.

Although the more important *fungus* diseases affecting the potato crop have now been described, there are many others, but for a description of these more advanced text-books should be consulted. Fungi are not the only causal agents of disease, however, and reference must be made to another menace which threatens the potato crop—Potato Root Eelworm.

CHAPTER VI

THE POTATO AND EELWORM

EELWORMS are not insects or even true worms; they belong to the class of animal life known as Nematodes, which includes many important parasites affecting the health of man, domesticated animals and crops. Those which parasitize man and animals have been studied for a very long time, but plant-parasitic types, although known a century ago, have received less attention and it is only in relatively recent years that they have become the subject of more intensive research. The Nematodes that attack animals are comparatively large, but those causing disease in plants are very minute and the unaided eye cannot detect them in diseased tissue, although it can see the swollen females (*cysts*) of certain kinds which will be described later.

A wide range of cultivated and wild plants are susceptible to eelworm attack, and some crops such as the potato and sugar beet are so severely affected that their successful cultivation becomes impossible. This is well illustrated by what happened to the sugar beet industry in Germany in the seventies of the last century, when production had reached its highest peak. The first sugar beet factory had been opened there in 1802, and during the next thirty years the industry gradually developed. More farms started cultivating sugar beet. By 1836 one hundred and twenty-two factories were working. As the crop was so profitable, increasing attention was given to it: by 1860, improved methods of cultivation had raised the yield and sugar content, and there were two hundred and forty-seven factories. The industry was now well established, and more and more land was devoted to the crop. Unfortunately it gave such a good profit that farmers persisted in growing it wherever they could, and, without any rotation, *year after year on the same land*. Ten years later there were three hundred and four factories, handling over 3,000,000 tons of beet and

producing about 186,500 tons of unrefined sugar annually.[1] But the yield per acre was falling and the sugar content was not as good as it had been. The land was becoming "weary" of sugar beet—the soil was "sick". In 1876, several factories had closed down. What was the main cause of these sugar beet failures? Within a year or so the investigations of Liebscher, Kühn and others, made it clear that "beet sickness" was due to a Nematode. Continuous cultivation of the crop on the same land had resulted in the soil becoming populated with a root eelworm, *Heterodera schachtii*. It was present not only in Germany, for subsequent investigations disclosed that it was widely distributed in France, Finland, Holland, Austria, Hungary, Bohemia and western Russia. But to return to the eelworm pests which plague the potato crop.

There are two eelworm pests of the potato, Root Eelworm and Stem Eelworm. The former is caused by *Heterodera rostochiensis*, the latter by *Anguillulina dipsaci*. Of the two, Root Eelworm is by far the more important. During the past thirty years its course has run unchecked; it is now widespread and a serious menace to the successful cultivation of the crop. Unless potato growers appreciate the danger, recognize the symptoms of Root Eelworm and do their best to control it by a sound sequence of cropping, many acres of land hitherto fertile will become "potato-sick". What are the symptoms of Root Eelworm, its life cycle and method of prevention?

POTATO ROOT EELWORM (Heterodera rostochiensis)

In England, Root Eelworm was first found on sickly potatoes in Yorkshire in 1917, but it is very probable that at that date it was already present in other areas, for within two or three years it was found in widely separated districts and it is now distributed throughout Great Britain.

For many years it was thought that the pest was a variety of the Root Eelworm which attacked sugar beet on the Continent and it was called *Heterodera schachtii* var. *Solani*; it is now realized, however, that a different species is concerned and it is named *Heterodera rostochiensis*. As

[1] *Die Zuckerindustie*, R. v. Kaufmann, 1878.

far as is known at present, Potato Root Eelworm will not attack any other commonly grown farm crop, but it does attack tomatoes. Many farmers still believe that the eelworm on potatoes and sugar beet are the same pest. This is not correct. Potato Root Eelworm does *not* attack sugar beet, nor does the Sugar Beet Eelworm affect potatoes.

Symptoms of Potato Root Eelworm.—Plants badly affected with Root Eelworm have weak, spindly stems with stunted and sickly foliage, and at an early stage the lower leaves turn yellow and wither and the plant dies. Plants with these unhealthy signs may be seen in a patch or patches in the field or they may be more generally distributed. These symptoms alone, however, are not a sufficient guide on which to base a diagnosis of eelworm attack, for certain parasitic fungi injure the root system and the lower portion of the stem and, by restricting the flow of sap in the plant, bring about a somewhat similar unhealthy appearance of the haulm. It is necessary therefore to verify the presence of this pest by pulling up the plant and examining the root system, preferably with the aid of a pocket lens. If the plant has been severely injured by eelworm, it will be seen that there is an abundance of lateral rootlets, many of the small ones being dead. A few tubers only will be present and these will be small. On a closer examination of the roots it will be seen that some are infested with small round bodies about the size of a pin head. At first they are dull white, but soon turn yellow and later dark brown. These are "cysts", the dead swollen bodies of female eelworms full of eggs.

Life Cycle.—The encysted females (the only stage of the eelworm which can be seen by the unaided eye) drop off the rootlets into the soil where they remain dormant over the winter. In each cyst there are a large number of eggs, the number depending upon the size of the cyst: in some there are only a score or so, in others a hundred or more. The eggs do not all hatch out at the same period but a few at a time over a number of years, and, in the absence of a suitable food plant, some may remain alive for eight or nine years. When a potato crop is grown, however, it seems that a stimulation is provided by some excretion from the roots, and the rate of hatching is

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Cyst contaminated seed is sown on clean land or clean seed on infested land.

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The eelworms hatch and break out of the cysts when the potatoes begin to grow.

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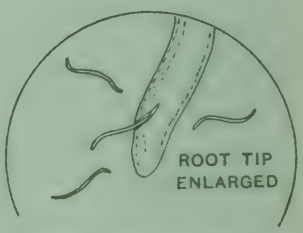

Young worms bore into the roots and kill them.

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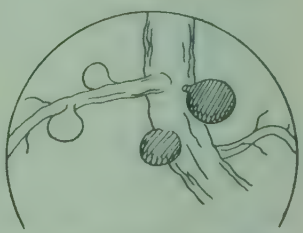

On the roots female eelworms form white cysts which turn yellow and then brown.

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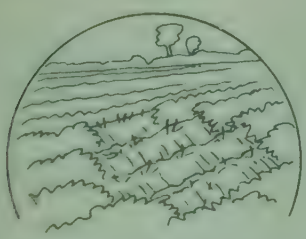
Badly infected plants are stunted and have many extra fibrous roots. The lower leaves turn yellow and drop off.

6



The plants die off where the soil is very heavily infested.

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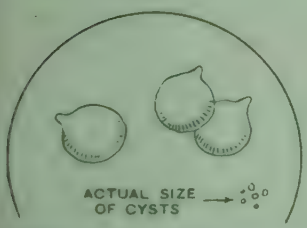

When the potatoes are lifted the majority of the cysts remain in the soil.

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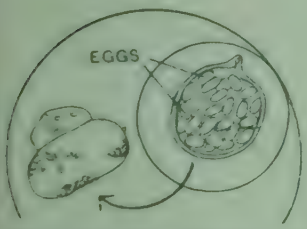

But the soil adhering to the tubers will also contain a few cysts.

9

Clean land may become contaminated with infested soil carried on boots and implements.

THE LIFE CYCLE OF *HETERODERA ROSTOCHIENSIS* — THE POTATO ROOT EELWORM

FIG. 11. THE POTATO ROOT EELWORM

greatly increased. On hatching, the tiny eelworms find their way to the potato rootlets, penetrate into the tissue and eventually kill them, but at this stage they cannot be seen by the unaided eye. This invasion of the roots does not always lead to the premature death of the plants, even though many eelworms may be present. Why plants should be able to withstand or "throw off" the attack in some cases, and not in others, is not clear, but it is probably intimately connected with the size of the eelworm population. It has also been suggested that it may be related in some way to the general vigour of the plants, and their readiness to produce additional roots to replace those which have been destroyed.

Contamination of Clean Land.—Naturally enough farmers are mystified when they realize that their fields are becoming "potato-sick" and wonder how it has come about. As a few infected plants easily escape notice, it is probable that eelworms were present in the soil several years before the first unhealthy patch or patches in the field were observed. These infested plants contaminated the soil, and, if potatoes were grown too frequently in the sequence of cropping, the patches tended to become larger and larger until they were noticeable. But how in the first instance does the pest gain access to the field? That question often puzzles the farmer and smallholder. Eelworm cysts are carried from an infested field to a clean one in soil adhering to boots, animals' feet, carts and farm implements. Another means, and a more certain one, is by cysts present in small lumps of soil on the seed tubers themselves.

CONTROL MEASURES. In spite of much research, no satisfactory chemical treatment, suitable to field practice, has yet been devised which has been *universally successful in killing eelworm in the soil.* Good crops have been grown, however, on "potato-sick" land by the use of certain fertilizers and partial soil-sterilizing agents. "Calcium cyanamide has given good results in parts of the north-west, potash in Devon, and at times naphthalene in Lincolnshire. Heavy dressings of farmyard manure are also said to have been temporarily effective. None of

these dressings have, however, been consistently successful throughout the country, and it seems evident that their value has been due rather to their effect on the plant than upon the eelworm: by encouraging active root formation, they have enabled the plant to develop in spite of what would otherwise have been a serious attack."[1]

As no successful chemical treatment has yet been discovered for destroying the pest in the soil, it is clear that every effort must be made to starve it out. This can be done only if a wise sequence of cropping is planned, and potatoes are not grown too frequently on the same land. On land where the eelworm population is low, potatoes should be grown *only once in four years*. On land which is badly infested an interval of from five to seven years or more should elapse. In the intervening period great care should be taken to keep down "ground keepers" (i.e. self-set potato plants), and outdoor tomatoes should not be grown.

To prevent the introduction of cysts to clean land it is important to obtain seed potatoes from land which is free from eelworm, and, as far as is practicably possible, to take special care that no soil from an infested field is carried to a clean one.

POTATO STEM EELWORM (*Anguillulina dipsaci*)

This Nematode was first described by Kühn in Germany in 1888, and it is now known that there are several races of it which specialize on different crop plants. It was not until 1922, however, that it was recorded as attacking potatoes in England, although other races of it were known to injure farm crops such as oats and clover. It is very probable that it had been present long before this, and that the diseased tubers had been mistaken for blighted ones.

Symptoms of Potato Stem Eelworm.—In the field, owing to the lack of any well defined symptoms on the stems and foliage, it is not possible to identify plants parasitized by Stem Eelworm, and it is not until the tubers are examined that the injury can be seen. The symptoms on these are somewhat similar to those caused by the

[1] *Advisory Leaflet* No 284, Ministry of Agriculture and Fisheries, 1944.

Blight fungus. Discoloured areas show on the tuber and the flesh underneath is brown. When badly affected, the skin over the diseased part tightens and cracks appear on the surface. At this stage the tissue underneath is not firm, as it is in Blight, but has a spongy texture. Unlike Potato Root Eelworm cysts are not formed, and so the pest itself cannot be detected by the unaided eye. To be certain therefore that Stem Eelworm is responsible for the condition, and not some fungus parasite, it is necessary to examine the diseased tuber microscopically. It is for this reason that farmers, who suspect that this disease is present on their farms, should submit diseased tubers to an expert for examination.

CONTROL MEASURES. These are very similar to those practised for the control of Potato Root Eelworm, but as Stem Eelworm is a less persistent pest it is usually sufficient to allow three years between potato crops. Care should be taken that no soil from an infested field is carried to a clean one, and weeds should be kept down as some of them may harbour the pest.

CHAPTER VII

DISEASES OF SUGAR BEET AND MANGOLDS

During the nineteenth century several attempts were made to establish a beet-sugar industry in England, but these met with little or no success. Although many factories existed on the Continent there were none here, and such sugar beet as was produced was shipped abroad for sugar extraction. In 1912, however, a factory was started at Cantley in Norfolk, and the acreage devoted to the crop then increased from some 500 to 11,000 acres. Its work was interrupted, for it was closed down during the latter part of the First World War and did not open again until 1920. The following year another factory was opened at Kelham, near Newark, but it was not until 1924, when the Government subsidy on home-produced sugar was provided, that this new industry received any stimulus or made any substantial progress. From then onwards the industry grew rapidly, and in 1945 there were eighteen factories and over 400,000 acres devoted to this crop in England, Wales and Scotland, giving a total yield of nearly 4,000,000 tons of sugar beet. The sugar extracted from this was sufficient to cover the domestic ration of 8 oz. per person per week.

When a crop is first introduced into a country it usually remains relatively free from disease for a number of years, but, as it becomes more generally grown, especially if taken too frequently on the same land, the causal agents of disease accumulate and trouble appears. So it was with the sugar beet crop: at first the crops were healthy but after a few years local field observations and large-scale field surveys disclosed the presence of many ailments. The causes of some of the more important of these, and the measures taken to control them, are now described. For convenience they are divided into three categories: diseased conditions of the seedling, leaf, and root.

SEEDLING DISEASES

Seedlings of sugar beet and mangolds are often described as suffering from "black leg". Unfortunately the term is frequently used in a wide sense to indicate any unhealthy state of the young root or stem, especially if the affected parts are discoloured. It is necessary there-

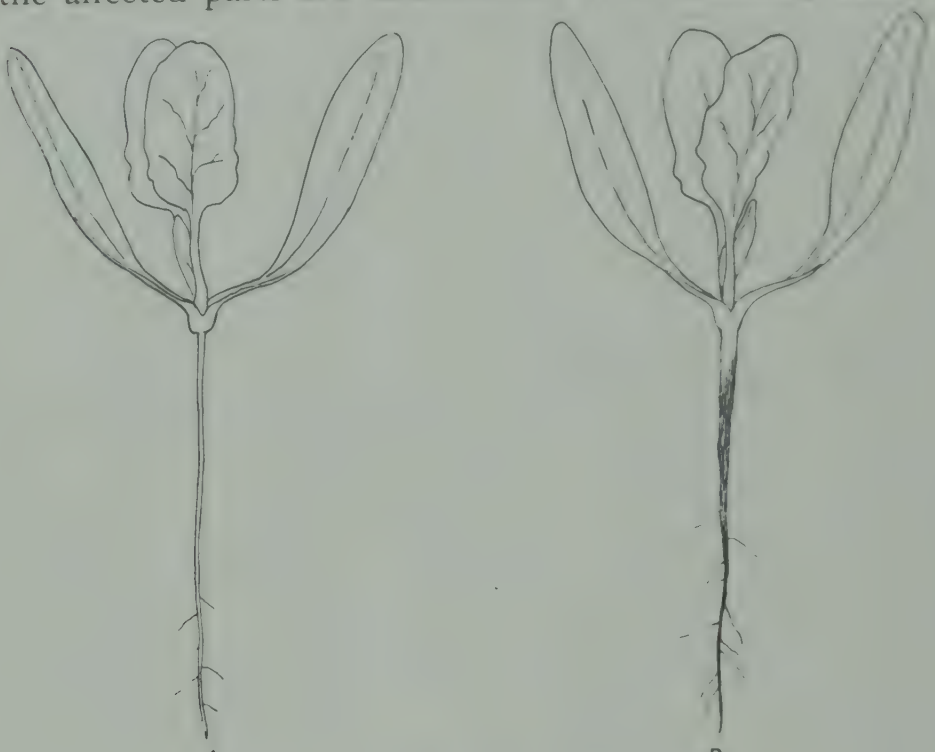

FIG. 12. SUGAR BEET SEEDLINGS
(A) Stringy root. (B) Black Leg.

fore to consider this "disease" in more detail and to examine the cause of it. The plant pathologist uses the term Black Leg to describe a condition of the stem which results in a blackening and shrivelling of the tissues just below soil level. The affected parts are reduced to black cotton-like threads, and the seedlings wither and die. The cause of Black Leg is not always easy to determine, but usually it is associated with the presence of one or other of certain fungi. One of these is seed-borne, the others inhabit the soil.

The seed-borne fungus is *Phoma Betae*, and it hibernates as spawn in the tissues which surround the seed clusters. It is common on beet seed samples, and, when

conditions favour its growth, it invades the germinating seed. When this happens diseased areas appear on the young stem at, or just below, soil level; these increase in size, turn brown, then black, and finally the seedling dies. If the plant is attacked when it is older and growing vigorously the diseased area may be sloughed off and recovery takes place. Although *Phoma Betae* may be present in seed clusters, Black Leg does not always appear, for much depends upon weather and soil conditions. If these are not favourable to quick and steady growth, and the seedlings are slow in pushing through the soil and becoming established, disease is likely to develop; but, under more congenial conditions, the loss of plant is usually negligible.

Apart from *Phoma Betae,* Black Leg may be caused by certain soil-inhabiting fungi such as *Pythium*. This type of Black Leg is not usually distributed evenly through the field, as is the case with a *Phoma Betae* attack, but appears in patches, especially if the land is waterlogged or badly drained. Although the cause of this condition is not always easy to ascertain, care should be taken not to confuse it with injury brought about by the Pigmy Mangold beetle (*Atomaria linearis*). Characteristic beetle damage is distinguished from Black Leg by the small holes which are bitten out from the seedling at soil level. Plants wounded in this way may later succumb to fungus attack. Stringy Root is another ailment which is sometimes mistaken for Black Leg. This condition is one in which the stem axis fails to swell normally, and becomes thin, hard and stringy, but seldom black and rotten. It is not due to any insect pest or fungus disease, but to faulty nutrition. It is prevalent on acid soils.

CONTROL MEASURES. All sugar beet sown in this country is now treated with an organo-mercury seed dressing before it is dispatched to the farmer. This dressing affords protection to the developing seedling and reduces the chances of fungus attack, especially when the weather is cold and wet and germination slow, but it will not prevent ailments which arise from faulty nutrition, poor drainage or sour soils. If Black Leg or Stringy Root

occurs, therefore, it is likely that some adverse soil condition is the cause and this should be remedied.

FOLIAGE DISEASES

The leaves of sugar beet and mangolds are attacked by several parasitic fungi, but, with one or two exceptions, the damage they cause in this country is negligible. Occasionally, late in the season, Leaf Spot appears; this may be caused by the leaf spotting fungi *Cercospora beticola* or *Ramularia beticola,* but in normal seasons the injury is very trivial. In some countries they are of more consequence and attempts are then made to check the disease by the application of spray fluids, but in England these precautions are not necessary. Rust (*Uromyces Betae*) sometimes appears, especially on crops grown for seed, but here again it is seldom serious. As with most Rusts it is more severe when crops are liberally supplied with quick-acting nitrogenous fertilizers.

Three other diseases which sometimes occur need more attention, and, as the causal agents are quite different, they must be considered separately. They are Downy Mildew, caused by *Peronospora Schachtii*, Yellows, a virus disease, and Speckled Yellows, a deficiency disease due to the absence or non-availibility of manganese in the soil.

Downy Mildew (*Peronospora Schachtii*).—The natural duration of a sugar beet or mangold plant is two years. In the first year it stores up food, chiefly in the form of sugar, and in the second it uses this to form a flowering shoot to produce seeds. At any stage in this life cycle the plant may be subjected to an attack by the spores of the fungus *Peronospora Schachtii*, which give rise to the disease known as Downy Mildew. If this develops the intensity of the disease will depend upon certain climatic conditions. In warm and humid weather the attack may be severe and, in the case of the root crop, there will be a loss in yield and sugar content. If, however, the crop is being grown for seed the consequence may be more serious, for the yield of seed may be markedly reduced.

Normally Downy Mildew is first observed in the field about June or July, on the young inner heart leaves, which are stunted, distorted and curled. If these are examined

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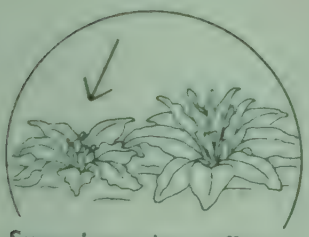


Sugar beet plants affected with Downy Mildew are found in the root crop.

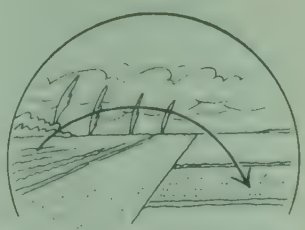
2

A diseased plant—the centre leaves are curled and covered by a lilac mould.

3

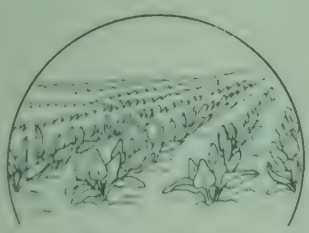
This mould, shown greatly enlarged, consists of stalks bearing countless spores.

4



Spores from the root crop are blown on to sugar beet plants being raised for seed.

5



Some of these seed plants will become infected.

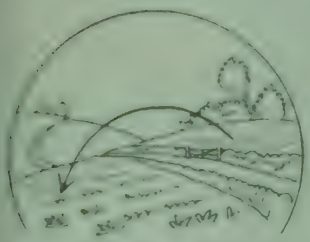
6

Later when they are planted out the mildew will spread to healthy seed plants.

7

From infected seed plants the spores are blown on to a neighbouring root crop.

8



The root crop becomes infected.

THE LIFE CYCLE OF *PERONOSPORA SCHACHTII* the fungus causing DOWNY MILDEW OF SUGAR BEET

To avoid mildew, root and seed crops should be well separated.

FIG. 13. DOWNY MILDEW OF SUGAR BEET

carefully a lilac-grey mould will be seen covering them, and at first this is usually on the under-surface. This mouldy appearance is caused by the fungus, and when observed under the microscope, it is seen to consist of delicate stalks bearing innumerable spores. It is these that are blown by the wind to infect other beet plants in the vicinity.

How is the disease brought about each year? Theoretically it may arise from one of the following: (1) the use of infected seed; (2) special resting spores contained in the debris from a previous infected crop; (3) spores blown in late summer to young seed plants, and then back from these in the following year to the root crop.

There is no proof that in this country infection originates from the use of infected seed, but under former bad systems of rotation, where beet crops were taken in succession, it is not unlikely that infection resulted from resting spores in beet debris or from hibernating mycelium in undecomposed crowns. There is, however, considerable field evidence that severe attacks in root crops may occur when they are situated close to mildewed seed plants, and that seed plants become severely affected if they are grown in the immediate vicinity of diseased root crops.

CONTROL MEASURES. A distance of 400–500 yards should separate a root crop from plants being grown for seed. If a crop for seed must be grown nearer than this to a root crop, the relative situations of the two should be such that the prevailing winds do not first blow over the root crop and so carry spores to the young seed plants. Further, when these seed plants are set out they should be planted as far away as possible from any field where roots are being grown. Any isolated diseased plants that are noticed should be lifted gently, a small hole dug, and the diseased plants completely buried. It is bad practice to lift such plants and then carry them away, because in doing so the spores are scattered and infection spread. Every effort should be made to keep down "volunteer" plants for these may harbour not only Downy Mildew but also Virus Yellows.

VIRUS YELLOWS

In some seasons, especially in eastern England, sugar beet tops turn yellow, and when this happens in July or August the yield is much reduced. Yellowing later in the season is not so harmful and causes less concern. Farmers usually attribute "yellowing" to various causes such as drought, excessive moisture, sour soil, faulty nutrition, fungus attack, or, if it occurs late, to what they often describe as "premature ripening". In some instances one or other of these explanations may afford the answer, but it is now known that the most common and important cause is a virus disease called Virus Yellows. Mangolds, spinach, spinach-beet, and some weeds, such as goosefoot, also suffer from it.

The symptoms of Yellows occur on the outer and older leaves, which become yellow, thick and brittle, although the young, central leaves remain green. After the leaves turn yellow, they are usually attacked by saprophytic fungi; the bright yellow-orange colour then disappears and they become brown and scorched. When these symptoms appear early in the season, growth is greatly retarded and a serious loss in yield results. Virus Yellows is spread from plant to plant by the aphis, and the two chiefly concerned are the common green potato aphis, *Myzus persicae*, and the bean and beet aphis, *Aphis fabae*. When an aphis feeds on infected plants it sucks up the virus and, if it then feeds on healthy plants, it injects this into the leaves and yellowing follows. Aphids therefore are the carriers or vectors of the disease, transmitting it from plant to plant. No other way is known by which infection takes place. Some farmers think that it can be passed on in the seed, but there is no evidence of this. The seed is free from virus and consequently the young seedling starts life with a clean bill of health, but once the leaves appear, and aphis is present, infection may occur. The risk of this happening is very great if the root crop is situated near sugar beet plants being grown for seed, for the virus can overwinter in them and consequently they are a potent source of infection.

CONTROL MEASURES. To prevent Yellows the sources

of infection must be reduced to the minimum. A root crop should *never* be grown in the immediate vicinity of sugar beet and mangold plants being grown for seed purposes. The steckling bed should be well isolated, and when the beet are transplanted these should be as far away from a root or seed crop as possible. Important sources of infection are "volunteer" plants or "ground keepers", and care should be taken at harvest time to reduce them to a minimum. The normal life cycle of sugar beet and mangold plants is two years, consequently, if small roots are left in the field as not worth harvesting or large crowns are left because of bad topping, these will serve as fertile sources of infection for the following year's crop. Similarly odd mangold and red beet plants left lying about on clamp sites are a potential danger to nearby sugar beet crops.

Mosaic is another virus disease transmitted by the same aphids but it is less serious than Yellows. The symptoms of Mosaic are a bold green and yellow mottle of the central leaves which later become crinkled and distorted. The control measures are the same as for Yellows.

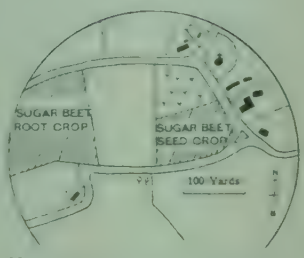
SPECKLED YELLOWS

This disease is a nutritional disorder and results from a deficiency in the soil of manganese in a form available to the plant. It is not widely distributed and is confined to certain soil types, especially thin peaty soils overlying chalk subsoils. If land contains much organic matter, however, it may occur after heavy applications of lime have been given. The symptoms of Speckled Yellows are fairly characteristic, although at an early stage they are sometimes confused with Mosaic. The first signs are pale yellow-green areas between the veins, followed later by the appearance of yellow or white specks. These darken in colour, turn brown, and often their centres fall out leaving small holes. When sugar beet shows signs of Speckled Yellows, it is likely that certain other crops when grown on the same land will also be affected with nutritional disorders. Thus potato haulm may become sickly-looking, Grey Leaf may appear in oats and Marsh Spot in peas.

1

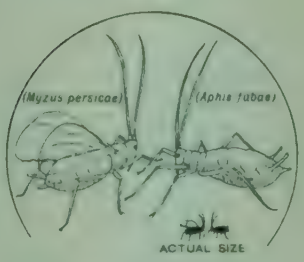
These seed plants are infected with Virus Yellows.

2



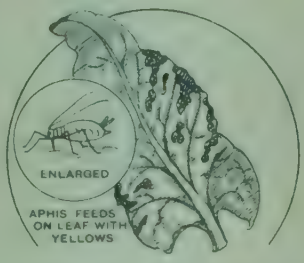
If a root crop is grown near the seed plants it may become infected.

3



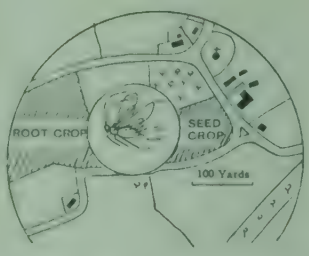
The virus is carried in these aphids from the seed plants to the root crops.

4



The aphids feed on the leaves of seed-plants and suck up the infected sap . . .

5

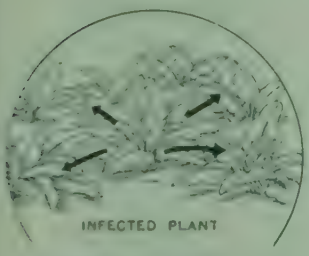


. . . which they then transfer to the neighbouring root crop.

6

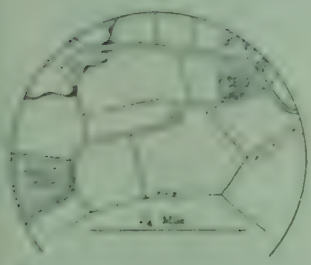
When an aphis containing virus-infected sap feeds on a healthy plant, this also becomes infected.

7



An infected plant is now a source of infection for others.

8



If the root crop had been kept farther away from seed-plants there would have been less Yellows.

VIRUS YELLOWS

A Disease of

SUGAR BEET

FIG. 14. VIRUS YELLOWS

FOOD TECHNOLOGICAL LIBRARY

CONTROL MEASURES. The remedy for Speckled Yellows is the application of a manganese salt, such as manganese sulphate. This can be sprayed on the growing crop or applied as a dressing to the soil. If Speckled Yellows is suspected, however, a confirmation of the diagnosis should be obtained, and expert advice sought as to the precise remedial measures to be adopted.

ROOT DISEASES

Violet Root Rot caused by *Helicobasidium purpureum* is the commonest fungus disease affecting the roots of sugar beet and mangolds, but there are two other important disorders that must be noted, namely, "beet sickness" due to the infestation of the roots by the parasitic nematode *Heterodera schachtii*, and Heart and Dry Rot, an ailment resulting from a deficiency in the soil of available boron. A brief description of each of these troubles is now given.

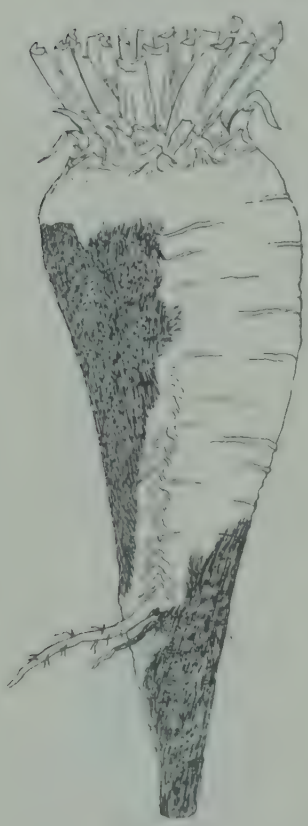


FIG. 15.
VIOLET ROOT ROT OF SUGAR BEET
(*Helicobasidium purpureum*)

VIOLET ROOT ROT (Helicobasidium purpureum)

The fungus causing Violet Root Rot inhabits the soil, but it grows very slowly and the disease is usually confined to small areas in the field. It is a troublesome disease and of common occurrence in England, but it is seldom of serious consequence. Although it appears most frequently on land that is poorly drained or in low-lying parts of fields, it is sometimes found on the lighter types of soil, and wherever it occurs it is difficult to eradicate. A wide range of crop plants are affected, including all kinds of beet, mangolds, carrots, potatoes, clover, lucerne, asparagus and occasionally celery and field beans. White-straw crops do not appear to be attacked. The signs of disease are not usually observed until the crop is lifted, when it

is noticed that soil sticks to the roots and cannot be shaken or brushed off. When the roots are washed, however, the soil comes away, and it is then seen that the surface is covered with patches of a purple felt-like spawn on which are scattered minute dark coloured bodies about the size of a pin point. These are not spores but organs which enable the fungus to penetrate the root and absorb the sap.

CONTROL MEASURES. The appearance of Violet Root Rot may indicate that the drainage is poor, and if so an attempt should be made to improve it. Affected roots should not be left lying about on the ground but should be collected and destroyed. If the attack is severe, susceptible crops should not be grown on the same ground for several years.

BEET EELWORM (*Heterodera schachtii*)

In Germany, and other Continental countries, the too frequent cropping of land with sugar beet lead to a condition known as "beet sickness". It was thought at first that this was due to a lack of some soil nutrient necessary for plant growth, but later it was discovered that the eelworm *Heterodera schachtii* was the cause. Although prevalent on the Continent, Beet Eelworm was not found in England until 1928 when it was discovered on mangolds near Bristol; in 1934 it was again found on mangolds and, for the first time, on sugar beet in the Isle of Ely, and later elsewhere. It is now known to be present in several other counties, the chief centres of infection being the Isle of Ely and Norfolk. The appearance of this pest is a menace to the successful cultivation of sugar beet, and farmers should always be on the watch for it. The presence of Eelworm should be suspected if a small patch, or patches, of stunted and sickly looking plants appear in the crop. These, of course, do not necessarily imply that the trouble is "beet sickness", but, if the roots are lifted, the suspicious symptoms can be further confirmed. The tap roots of affected plants are small and short, and are easily pulled from the soil. There is an abundance of lateral rootlets, and these "hunger roots" as

they are sometimes called, give a beard-like effect to the beet. Present on these rootlets, most of which are dead, are lemon-shaped cysts, at first creamy-white in colour but later becoming brown. As already noticed with Potato Root Eelworm, cysts are the dead bodies of female eelworms which form a protective covering for a large number of eggs.

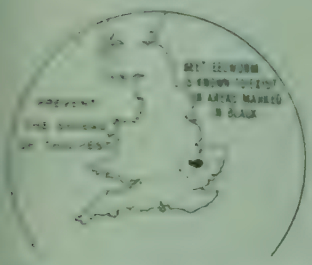
Life Cycle.—The cysts drop off the rootlets into the soil, where they remain dormant over the winter. In the spring *some* of the eggs hatch and, if the right host plant is present, the young eelworms penetrate the rootlets, killing them as they do so. More fibrous roots are formed to take their place, but these too may be attacked and die. As the female grows it protrudes from the root and, after fertilization, becomes full of eggs. It then dies, the egg-containing cyst remaining attached to the dead rootlet. It should be noted, however, that only a portion of the eggs hatch each year, and that some stay alive for six years or more. As might be expected the number of eelworms in the soil gradually increases if plants on which they feed are grown in succession or too frequently. When this happens "beet sickness" becomes acute. The crops susceptible to Beet Eelworm are sugar beet, red beet, spinach, turnips, swedes, cabbages, cauliflowers, broccoli, brussels sprouts, kale, rape, kohl-rabi, cress, mustard and radish. Certain weeds such as fat hen and charlock also harbour the pest. Some farmers think that Beet Eelworm will attack potatoes, but it does not do so, "potato sickness" is caused by a different eelworm.

CONTROL MEASURES. Prevention is better than cure. Great care should be taken to prevent land free from eelworm from becoming accidently contaminated. This may happen in one of many ways for cysts may be carried from infested ground to clean land in soil sticking to farm implements, carts, lorries, boots, etc. Another means, not sufficiently appreciated, is that it can be transferred in the soil present on the roots of plants grown for transplanting, such as beet and mangold stecklings, cabbages and celery. Another source is in small lumps of soil adhering to seed potatoes. But when land does become infested and

1

When patches of sickly looking beet occur the cause may be Beet Eelworm.

8



On infested fields adopt a rotation in which susceptible crops are not taken more than once in four years.

2

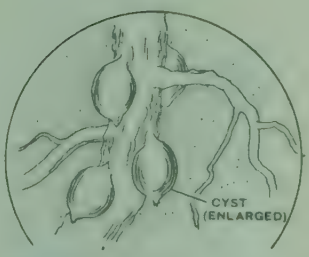
A heavily infested plant has this appearance.

THE LIFE CYCLE OF *HETERODERA SCHACHTII* THE BEET EELWORM

7

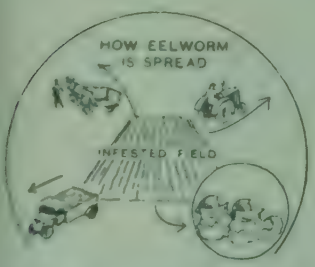
Soil, for example, tipped from carts which have carried infested beet may contaminate clean fields.

3



Eelworm cysts full of eggs are attached to the fibrous roots.

6

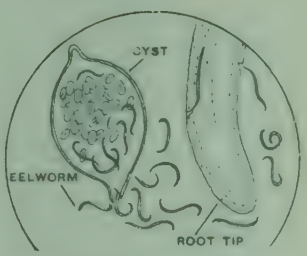


Infested soil on implements, boots, etc., spreads the eelworm cysts.

5

Beet Eelworm attacks plants of the Cabbage family—(*Cruciferae*)—*as well as* Sugar Beet, Red Beet and Mangolds.

4



From the eggs young eelworms hatch and bore into the roots; later they form cysts.

FIG. 16. THE BEET EELWORM

"sickness" appears, what then? As no satisfactory means have yet been discovered whereby Eelworm can be destroyed in the soil by chemical treatment, it is necessary to starve the pest from the ground by a suitable sequence of cropping. On land which is slightly infested, beet and other susceptible crops should be grown only once in every four years. A period of at least five years should elapse, however, if the soil is heavily infested.

To prevent Beet Eelworm from spreading and becoming firmly established in this country, an Order for the control of the pest, the Sugar Beet Eelworm Order, 1943, was made by the Ministry of Agriculture and Fisheries. The main provisions of the Order are: "Except under a licence from the War Agricultural Executive Committee for the County or County Borough concerned, no person may sow or plant sugar beet, mangold, red beet, spinach, cabbage, kale, cauliflower, broccoli, brussels sprouts, turnip, swede, mustard, cress, radish, kohl-rabi, or rape on any land in which sugar beet eelworm is known to be present, or on any land within an 'Infected Area' on which any of these crops have been grown during the two preceding years. An area lying within the counties of Cambridge, Huntingdon, Isle of Ely, Norfolk and Suffolk West is scheduled as an 'Infected Area' under the Order, in addition to smaller areas in the counties of Leicester, Norfolk and Suffolk West; other areas may be similarly scheduled in the future if necessary.

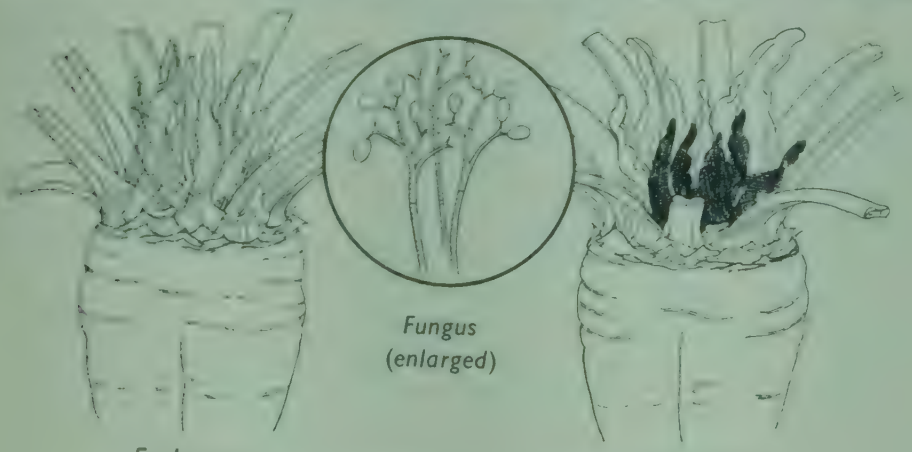
Potatoes grown on land on which the beet eelworm is known to exist may not be used for planting except on land forming part of the same holding."[1]

HEART AND DRY ROT

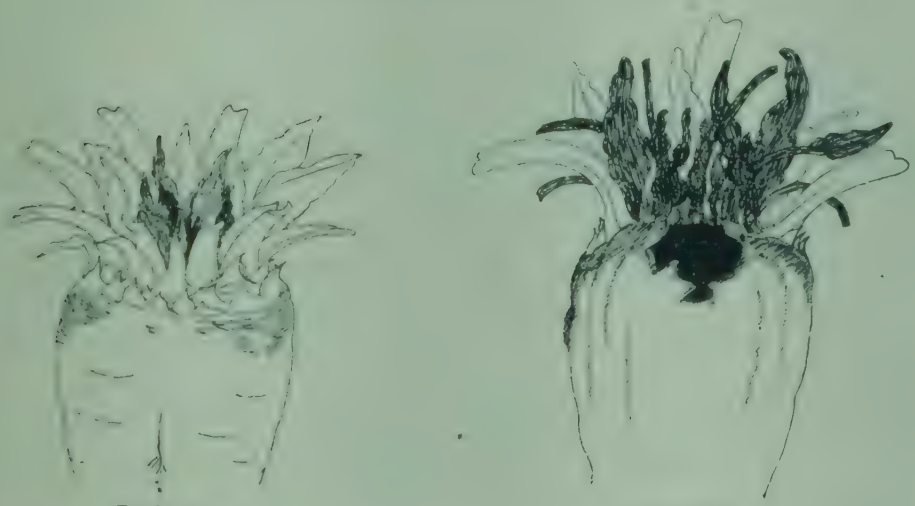
This disease of mangolds and sugar beet has been known for a long time, and in the past much controversy has arisen as to the nature of it. Some have attributed it to injury caused by the fungus *Phoma Betae*, others have maintained that it was not a parasitic disease but a nutritional disorder, and that the fungus appeared after the trouble had developed. Those most closely concerned with the study of Heart and Dry Rot, however, agreed

[1] *Advisory Leaflet* No. 233, Ministry of Agriculture and Fisheries, 1943.

that its occurrence and intensity was much influenced by the reaction of the soil, and to some extent by weather conditions, for it was usually more prevalent in dry seasons. It seemed to be favoured by light, alkaline soils,



Downy Mildew (*Peronospora Schachtii*)



Heart and Dry Rot caused by a deficiency of boron.

FIG. 17. SIMILARITIES BETWEEN DOWNY MILDEW AND HEART AND DRY ROT OF SUGAR BEET

or those which had been made alkaline by liming or by the continual use of alkaline fertilizers. The modern view is that Heart and Dry Rot is a disease due to boron deficiency, induced by alkaline soil conditions making the boron in the soil unavailable, especially in a dry season.

Symptoms.—The first visible signs of Heart and Dry

Rot are an unhealthy appearance of the young, central heart leaves. These cease to grow, curve slightly outwards, wilt, turn yellow, and finally become black and rotten. Later the outer leaves may die also. The plant strives to recover, however, and the crown often produces several groups of small leaves. If showery conditions favour growth these grow more or less normally, but in less favourable circumstances they remain small and often deformed.

The term Dry Rot refers to a condition that may follow after the heart leaves are dead. When this occurs the tissues at the crown become brown or black, the discoloration spreading downwards, in severe cases into the internal parts of the root. In those less badly affected it is confined to the outer part. Later a slow decay may set in and a form of dry rot appear. The fungus *Phoma Betae* is then sometimes associated with the decay, but it is not usually the direct cause of the condition, although it may aggravate it.

CONTROL MEASURES. Heart Rot can be prevented by applying to the soil small quantities of a boron compound, such as borax; but expert advice should always be sought before doing so, for if used incorrectly more harm than good may be done. There is another reason why an expert opinion is often necessary. Other diseases may be mistaken for Heart Rot: late in the season the heart leaves of plants affected with Downy Mildew often turn black and die, and when this happens it is sometimes difficult to distinguish the two conditions without the aid of a microscope.

CHAPTER VIII
DISEASES OF BEANS

In recent years there has been much controversy about the field bean crop, especially winter beans, and it is said by many farmers that the yields now are less than they used to be; but is there any positive and reliable evidence that this is so? Are the yields now less than they were in the days of ancient Egypt and of Rome, for beans have been cultivated from remote times. Pliny, in his *Natural History*, Chapter 45, says: "If the ground, too, is hoed three times, a modius of beans in the pod, they say, will yield not less than a modius of shelled beans." Perhaps the Romans, too, were wont to argue this matter—maybe the yield of beans was never as good as it used to be! It is a moot point, however, for in the past hundred years the yields do not seem to have deteriorated, although the acreage devoted to them has declined considerably. The area of beans grown in England and Wales in 1933 was under 140,000 acres, whereas fifty years or so ago it was in the region of half a million. This decline in bean growing was due largely to rising labour costs and the importation of foreign-grown beans; but, at the outbreak of war in 1939, it became an urgent necessity to produce more and more home-grown food stuffs, and a revival in bean growing took place and the acreage increased. In Stephens' *Book of the Farm,* published in 1844, it says: "The produce of the bean crop varies from 20–40 bushels per Imperial acre, much of the prolificacy of the crop depending on the nature of the season. . . ." More recent reference books place the yield at between 30–40 bushels, and 25–30 cwt. of haulm or straw per acre, whilst others suggest that the average yield is about 36 bushels of grain and 25 cwt. of straw. All are agreed, however, that the yields are variable and depend upon the season. Why is it that weather plays such an important part in determining yields? Apart from any question of encouraging or retarding the growth of the

crop itself, certain weather conditions favour disease. First, however, the effect of frost must be considered. Whenever the winter is at all severe some bean crops always suffer from frost injury; only occasionally, however, perhaps on an average of once in ten years, are they severely damaged. In general, crops ploughed in, or drilled early, suffer much less from frost than crops planted late. Although a crop may be "touched up" badly by frost and appear ruined, it often recovers in a surprising way because it produces new shoots from the base of the stem—it tillers well. This often occurs after a mild autumn and winter when the growth becomes too sappy and does not harden off. If a sharp spring frost then "catches" the plants they blacken and wither, but usually new shoots are formed and the plants recover. There is, however, a repercussion from frost injury, for the dead blackened shoots serve as a breeding ground for *Botrytis*, a fungus that causes the Chocolate Spot disease.

CHOCOLATE SPOT

This disease of broad- and field-beans occurs in a mild form almost every year, but severe epidemics are relatively uncommon. Has Chocolate Spot increased in intensity during the past twenty or thirty years? There is no reliable evidence of this. Moore, who has examined the reports on the prevalence of the disease over the past twenty-eight years, says: "During that period there have been serious epidemics over the greater part of the country on five occasions, or only about one year in six. In five other years local epidemics have developed, mostly in southern or western districts; in eleven years the disease has been more or less normal in incidence, while in seven years it caused only slight damage or was virtually absent."[1]

At one time it was thought that Chocolate Spot was a bacterial disease, the causal agent being *Bacillus Lathyri*, but it is now known that this is incorrect for it has been shown that species of *Botrytis* are responsible.

Symptoms.—These range from a characteristic spotting of the leaflets and streaking of the stems to an acute

[1] Moore, W. C. (1944). Chocolate Spot of Beans. *J. Min. Agric.*, 51, 266–9.

(*a*) Main shoot killed by frost, lateral bud breaking.

(*b*) Lateral shoot replacing main stem killed by frost.

(*c*) *Botrytis* grows on tissues killed by frost. Non-aggressive type of Chocolate Spot on foliage follows.

(*d*) Aggressive phase of Chocolate Spot.

FIG. 18.

FOUR STAGES IN THE DEVELOPMENT OF CHOCOLATE SPOT OF BEANS

condition where the diseased areas merge, causing partial defoliation, blackening and death of the plants.

Chocolate Spot infection is of two types, "non-aggressive" and "aggressive". The first form of infection (which should not be confused with bronzing and brown flecks caused by slight frosting) results in typical clearly marked chocolate-coloured spots. These symptoms can be found to a greater or lesser extent almost every year from December onwards, but the injury caused does not cripple the plant and is seldom severe. This is the limited type of infection, or as it is sometimes called, the "non-aggressive" phase. The second type of infection, which is much more important, leads to blackening and death of a part or the whole of the shoot system. This is the unlimited type, the "aggressive" form, and it is this which causes the damage when epidemics occur. The "aggressive" stage is usually limited to the months from April to July, and, if abnormally heavy rainfall occurs in these critical months, epidemics may be expected. Any adverse condition which weakens the crop, such as sour soil, potash and phosphate deficiency, waterlogging, poor drainage or a profusion of weeds, makes it more liable to the "aggressive" type of infection. Other factors favouring it are a dense stand of beans and shelter from prevailing winds.

Life Cycle.—Botrytis is a very common mould fungus found growing on dead or dying vegetation where, if weather conditions favour its growth, it produces abundant crops of spores. Later, when spore production has ceased, it forms small compact masses of spawn, and it is by means of these black resting bodies, called *sclerotia*, that it is able to survive for lengthy periods. On germination the sclerotia give rise to *Botrytis* spores, and the cycle starts anew.

It should be noted that *Botrytis* is both parasitic and saprophytic. Any dead or dying tissue present in the crop is likely to be a fertile breeding ground. For example, beans which have been severely frost-injured or have succumbed to Bean Rot, are likely centres for the production of enormous quantities of spores. It has been suggested[1] that the fungus may be carried over with the

[1] Moore, W. C. (1944), Chocolate Spot of Beans, *J. Min. Agric.*, 51, 266–9

1

The beans are sown

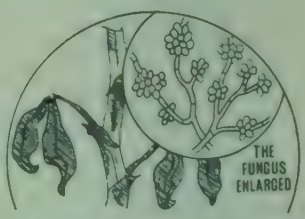
2

The seedlings are forward but growth is sappy and not hardened off owing to mild weather.

3

Sharp frosts and winds check the forward plants and shoots may turn black and die.

4

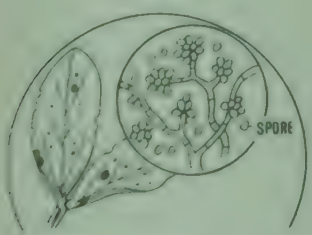


Spores of the common grey mould fungus (*Botrytis*) settle on the damaged tissues and become parasitic.

5

In favourable weather a lateral bud breaks and a healthy shoot is formed

6



Spores formed on the dead tissues fall on the young leaves.

7

Red spots and blotches appear. This is the "non-aggressive" form of the disease.

8

In very wet weather the disease may become "aggressive" and kill the whole plant.

9

Do not confuse these symptoms with the red marks caused by frost and aphis.

THE

CHOCOLATE SPOT

DISEASE

caused by the fungus

BOTRYTIS CINEREA

Frost predisposes the crop to the disease.

FIG. 19. CHOCOLATE SPOT DISEASE OF BEANS

seed and give rise to weak or diseased shoots covered with *Botrytis*; there is little evidence of this, and, if it did occur, it would seem to be of small importance for other sources of *Botrytis* are so abundant. But whatever the source of the spores they are blown away by the wind, or splashed abroad by rain, and subsequently infect healthy bean haulm. When few spores settle on the leaves, and weather does not favour infection, the "non-aggressive" form of Chocolate Spot results. If, however, the leaves are heavily bombarded with many spores and the weather conditions are ideal for infection (rain, high humidity, little or no wind and a temperature between 60°–70°F.) the disease develops in the "aggressive" form.

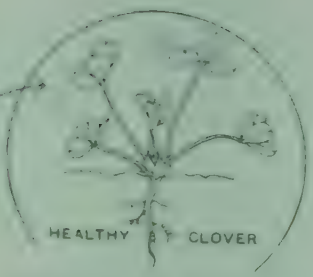
CONTROL MEASURES. No satisfactory method has yet been found of preventing Chocolate Spot, but the chances of damage may be lessened by correcting, where possible, those conditions which favour the disease, such as sour soil, potash and phosphate deficiency, waterlogging or foul land. Spring-sown beans suffer less from Chocolate Spot, and also Bean Rot, but unfortunately they are more susceptible to the bean and beet aphis, *Aphis fabae*.

BEAN ROT

When red clover is grown too frequently on the same field the crop often fails because the land has become "clover-sick". This "sickness" is not due to any lack of fertility, but to the contamination of the soil with the Clover Rot fungus *Sclerotinia Trifoliorum*. Besides clover this fungus also attacks other leguminous crops, and, in recent years, it has been shown to be the cause of Bean Rot. Severe attacks usually occur only when susceptible crops have followed too closely in the rotation. An odd plant or so will be found affected in most bean crops, but the effect in yield is then negligible.

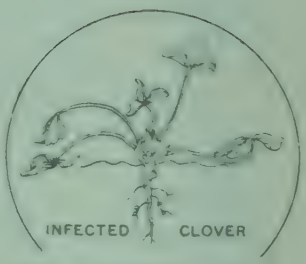
Symptoms.—Bean Rot becomes noticeable in winter-sown beans about mid-March or early April, but plants continue to die until harvest time. The plants wilt and die, weeds gain a hold, and what promised to be a full crop becomes a ragged one. If affected plants are pulled up—they come away very easily and this is a useful

1



The spores of the fungus *Sclerotina Trifoliorum* are falling on this healthy clover plant.

2



They germinate and infect the plant.

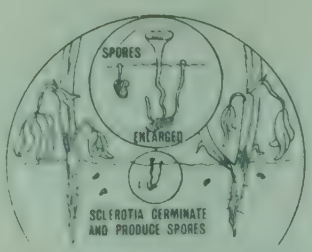
3

The clover dies and the fungus forms resting bodies called sclerotia, these contaminate the soil.

4

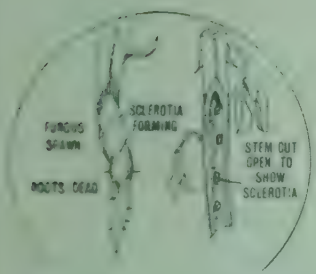
If a susceptible crop such as beans follows too closely it is liable to attack.

5



The sclerotia germinate and form cup-shaped bodies which produce spores; these fall on the healthy haulm.

6

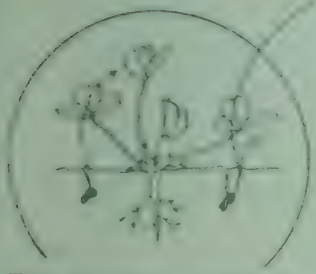


The plant is infected, dies, and more sclerotia are formed; these occur on and in the stems, and on the roots.

7

If another susceptible crop is taken too soon afterwards this also may fail.

8



The sclerotia germinate, more cup-shaped bodies are formed, and from these spores are scattered.

BEAN ROT

caused by the fungus

SCLEROTINIA

TRIFOLIORUM

Prevention—Do not grow beans on land that is clover-sick.

FIG. 20. BEAN ROT

diagnostic feature--it will be seen that the lower part of the stem and the upper portion of the root are covered with a whitish cobweb-like spawn. At a later date, when the disease is in a more advanced stage, the spawn becomes compacted into small cushion-like bodies, variable in size and of irregular shape. They are white at first but soon become black, resembling small pieces of coal, the largest being about the size of a pea. These resting bodies are sclerotia and they are a source of danger to both clover and beans, for they remain viable in the soil for several years. Not only do they form on the roots and stems at soil level, but also high up inside the stems; consequently many are carted away with the haulm when the crop is harvested, and find their way into the dung if diseased straw is used for litter.

Life Cycle.—During the summer the sclerotia remain dormant, but in the early autumn those within an inch or two of the surface of the soil germinate and produce flesh-coloured, saucer-shaped, stalked bodies called *apothecia*, from which spores are puffed out over a period of several weeks. Other sclerotia, more deeply buried in the soil, remain dormant for one or more years, but when cultivations bring them near the surface they too may germinate and produce spores which are blown by the wind to nearby plants or neighbouring fields. If the spores settle on bean haulm and the foliage is wet and the weather mild, infection results and later the symptoms of Bean Rot appear. More sclerotia are then formed, and the cycle renewed.

CONTROL MEASURES. As this fungus attacks only clover and related plants, the remedy for Clover and Bean Rot is to starve the fungus from the soil by growing only those crops which are resistant to the disease or less susceptible to it. On fields where Clover Rot has been severe, an interval of at least eight years should be allowed before common red clover or late-flowering red clover are taken again. During this period, sainfoin or lucerne can be sown or alsike or white clover may be substituted, either alone or with Italian rye grass. It is unwise to take winter beans in these circumstances, for although a good crop often

results, some of the plants will be attacked and more sclerotia formed. The fungus is then able to survive in the soil to the detriment of subsequent clover crops. Apart, therefore, from any consideration of reduced yields, winter beans serve as a bridge to carry the disease over from one clover crop to another. In this interval peas, vetches or *spring-sown* beans could be grown, as they escape the disease, but spring-sown beans are unfortunately very susceptible to attack from the bean and beet aphis, *Aphis fabae*.

To prevent the spread of sclerotia to clean land, it is suggested that where bean haulm from an *infected* crop is used for litter or feeding, it should be used first to insure its incorporation into the lower layers of the dung in the yards, as experiments have shown that the sclerotia decay more quickly here than they do nearer the surface. (See also Chapter X.)

Chocolate Spot and Bean Rot are the two chief diseases of beans. There are other leaf-spotting fungi such as *Ascochyta Fabae* and *Cercospora Fabae*, and Rust (*Uromyces Fabae*) is often common late in the season. The damage done by these fungi, however, is of little account.

Is it of any value to disinfect bean seed samples with seed disinfectants before sowing to prevent disease and protect the seed during its initial stages of germination? Experiments carried out at Cambridge have shown that seed disinfection with an organo-mercury seed dressing had little or no effect on growth and yield, and there was no obvious indication that the plants from the treated seed were less affected by disease than those arising from untreated seed. This, however, is not the case with peas and the diseases of this crop are now discussed.

CHAPTER IX
DISEASES OF PEAS

THE diseases of field peas are unlike those of field beans, and present rather a different problem in disease control. If the germination capacity of a sample of field beans is high, and it is sown under reasonably good conditions in heavy soil or medium loam, well-drained, and sufficiently supplied with phosphates and lime, a high field germination usually follows and the seedlings become readily established. Peas, however, although of high germinating quality, reasonably free from blemish, and sown on soil types best suited to their cultivation (open, well-drained soils containing an ample supply of lime) may give a poor germination in the field. Why is this? The successful cultivation of peas is often much influenced by weather conditions during the first few weeks after sowing. If these are adverse, so that germination is long delayed, the seed rots in the soil and a thin stand results. If, in these circumstances, the initial germination is not good, or the seed infected with certain parasitic fungi such as species of *Ascochyta,* the rotting of the seed is further aggravated and early failures occur. When weather conditions are such that they favour quick germination, however, the seedlings thrive and, provided they are not unduly checked by frost or drought, a full crop is obtained. When the seed fails to germinate well, it is usually due to certain soil-inhabiting fungi such as species of *Pythium* and *Fusarium,* and the resultant condition is known as *pre-emergence blight* or *damping off*. It seems, however, that serious injury to the seed takes place only when germination is considerably delayed, the soil cold and wet, or the seed already infected with seed-borne parasites. As might be expected it is early sown peas which suffer most.

CONTROL MEASURES FOR PRE-EMERGENCE DAMPING OFF. Avoid using samples with a high proportion of discoloured seed. Brown or purplish-brown discoloured patches on

the surface usually indicate the presence of *Ascochyta* or *Mycosphaerella* seed-borne fungi which, besides impairing germination, cause disease of the leaves and pods, and sometimes of the roots and stems as well. Peas do best on the more open, well-drained soils, and in these situations damping off will be less; but on heavier types, lying cold and wet, or in districts of high rainfall, it is much more likely to occur.

For sowings made early in the season the application of a suitable organo-mercury seed dressing is likely to result in an increased stand and yield of marketable pods, but it is doubtful if such a practice will be of any advantage for later sowings. The organo-mercury seed dressings are the same as those employed for the disinfection of cereal seed, and they should be applied as directed by the maker. They are usually used at the rate of 2 oz. to the bushel of seed, and the mixing operation is done in the same way as it is for seed corn. It should be noted, however, that these dressings do not prevent the seed-borne diseases of the pea crop, although they may cause some slight reduction in their intensity. Their value lies in protecting the seed from parasitic or weakly parastic soil organisms when conditions for germination are unfavourable.

FOOT ROT

In the early summer months, often towards the end of June, the lower leaves turn yellow and the plants wilt and die before the pods have had time to fill out. These sickly plants are not distributed uniformly throughout the crop, but usually occur in small patches. If the diseased plants are pulled up it is seen that the roots and the lower portion of the stems are brown and stringy. This condition is due to invasion of the tissues by *Fusarium,* a soil-inhabiting fungus, which, by attacking the conducting channels in the plant, restricts the flow of sap and causes wilting. Foot Rot of this type is often linked up with unsatisfactory soil conditions or the too frequent cultivation of the crop on the same land.

CONTROL MEASURES. For early sowings the seed should be treated with an approved organo-mercury seed

dressing, as the fungus may be present on the seed as well as in the soil. A sound sequence of cropping should be practised. If, in spite of these precautions, Root Rot appears, the soil conditions should be investigated. It is always advisable to examine the root system minutely, preferably with a hand lens, in case the plants are infested by the Pea Root Eelworm, *Heterodera gottingiana*. If this is the case, female eelworm cysts will be seen on the roots, but these are *not* a source of danger to potatoes or sugar beet. They will injure field beans and vetches, however, and consequently the pest must be starved from the soil by not growing susceptible crops for a number of years.

SEED-BORNE DISEASES

Leaf and Pod Spot is the name given to a disease which causes brown spots on the leaves and pods. It may be due to one of three fungi, *Ascochyta Pisi, Mycosphaerella pinodes* (these two are the most common) and *Ascochyta pinodella*. Apart from causing spotting of the haulm, however, they may cripple or kill the young seedling.

FIG. 21.
LEAF AND POD SPOT OF PEAS
(*Ascochyta Pisi*)

Symptoms.—The symptoms vary somewhat with the fungus concerned. If the infection is caused by *Ascochyta Pisi* the single spots on the leaves and pods are more or less circular, but these often merge together to form irregular patches. Diseased areas are light brown with a darker margin, and, if the disease has been present for some time, minute black specks appear on the surface. These are spore cases (pycnidia) containing spores which are released in wet weather, and it is by this means that the fungus is spread from plant to plant. On the leaves the spots are papery in texture, and on the pods noticeably sunken. When the infection is caused by *Mycosphaerella pinodes* or

Ascochyta pinodella smaller purplish-brown spots develop. The disease is more virulent in wet seasons and in districts of high rainfall.

Life Cycle.—The fungus spreads through the tissues of the pod and infects the seeds causing brown or purplish spots. As long as the seed is dry, the spawn remains dormant, but when sown it absorbs moisture and starts growing. From the seed leaves it spreads to the young shoot and so to the foliage leaves. Spore cases are formed on the diseased tissue and later spores are splashed on to neighbouring plants. The pods become infected, and finally the seeds. This cycle, however, may be cut short for *Mycosphaerella pinodes* and *Ascochyta pinodella* may so severely injure the young root and basal part of the stem that the seedling dies: *Ascochyta Pisi* may bring about a similar result by crippling the young stem.

CONTROL MEASURES. Avoid sowing discoloured seed samples, and for early sowings treat the seed with an approved organo-mercury seed dressing.

POWDERY AND DOWNY MILDEW

There are two distinct mildew diseases of peas and the common names by which they are known are Powdery Mildew and Downy Mildew. Powdery Mildew is sometimes referred to as "true" mildew, and Downy Mildew as "false" mildew, and the student should learn to distinguish between the two types. (See Fig. 22.)

POWDERY MILDEW

This mildew is caused by *Erysiphe Polygoni* and it exists in a number of specialized races. One of these attacks peas, covering the leaves with a white powder, and another causes mildew on swedes and turnips. Specialization of this kind is not confined to the powdery mildews but occurs in certain other fungi, notably those which cause the rust diseases of cereals and other crops. The race or strain which parasitizes peas can cause no harm to swedes, however, and a mildewed swede, or other *Brassica* crop, is not a source of danger to peas. There is little exact information as to the losses caused by the Powdery

Mildew, but towards the end of the season, especially in dry weather, crops are often smothered with it and it is then assumed that the disease is responsible for low yields. It may be, however, that these low yields are more a result of drought conditions than of disease.

Life Cycle.—As with many other Powdery Mildews there are two stages in the life cycle; a summer stage, when enormous quantities of wind-dispersed spores (conidia) are produced, and a winter stage in which resting bodies (cleistocarps) are formed. The attack in the spring starts from the spores released from the resting-bodies and the summer-spores then formed create the epidemic.

CONTROL MEASURES. Normally, in farm practice, no measures are taken to prevent mildew, but control of the disease can be achieved by dusting the foliage with finely-powdered sulphur, for this fungus, like other powdery mildews, is a surface feeder and penetrates only the skin of the leaves.

DOWNY MILDEW

The fungus causing Downy Mildew is *Peronospora Viciae* and it forms a grey mealy felt on the under surfaces of the leaves. Unlike Powdery Mildew the fungus is more prevalent in *wet* seasons, and the spawn does not feed upon the surface but penetrates deeply into the tissue. Although the injury caused is more severe than that brought about by Powdery Mildew, the disease is not so uniformly distributed in the crop and does not gain such a hold.

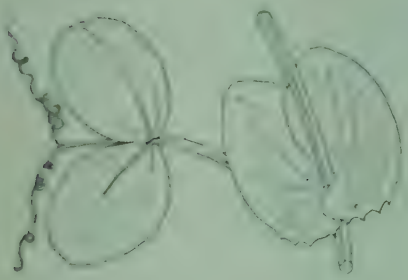
Life Cycle.—There are two stages in the life cycle but the spore forms are not the same as in Powdery Mildew. The summer spores are borne on much branched stalks (and not in chains) and the resting bodies are large spores (oospores) embedded in the diseased tissues—but these cannot be seen with the unaided eye. The first spring or summer infection probably arises from the resting spores present in the debris of diseased haulm in the soil. Summer spores are then produced on the diseased plants and scattered to healthy ones.

POWDERY MILDEW

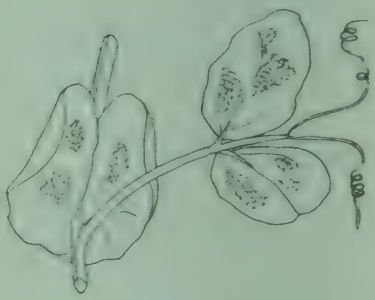
Erysiphe Polygoni

DOWNY MILDEW

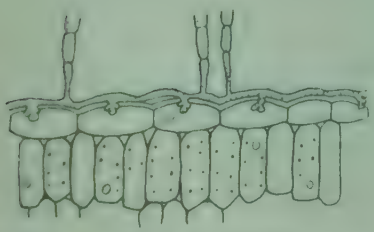
Peronospora Viciae



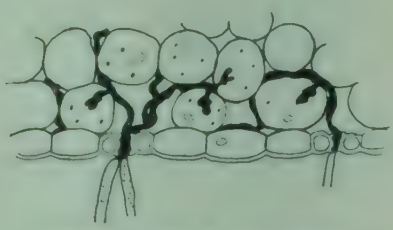
LEAF SYMPTOMS



CONIDIAL STAGE



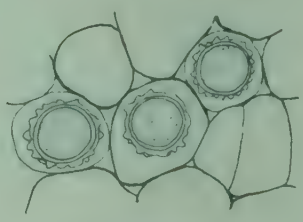
HYPHAE



Upper surface of leaf showing superficial hyphae

Lower surface of leaf showing intercellular hyphae

RESTING STAGE



Cleistocarp and Asci.

Oospores

FIG. 22. THE MAIN FEATURES OF A POWDERY AND A DOWNY MILDEW

CONTROL MEASURES. If a sound sequence of cropping is practised, and drainage good, Downy Mildew is not likely to be troublesome in normal seasons, but it does check growth when prolonged spells of wet weather prevail, and in districts of high rainfall it is sometimes serious.

MARSH SPOT

Marsh Spot was so named because it was known to occur in seed grown on certain marshy soils, particularly those near the sea, but it is also found on other types; for example, thin peaty soils overlying chalk subsoils or on land with a high content of organic matter that has been overlimed. The symptoms of Marsh Spot cannot be detected by examining the foliage, and it is not until the seeds are split open that the symptoms become apparent. A brown discoloration is then seen in the middle of each seed leaf (cotyledon), and if the disorder is acute the affected parts are slightly sunken.

Until recently the cause of this disorder (for it is not a disease caused by any known parasitic organism or virus) remained undiscovered; but it is now known that Marsh Spot is associated with a deficiency of manganese in the soil in a form available to the plant. Ailments or disorders of this kind are described as deficiency diseases and they are not uncommon. For example, a deficiency of this same element in an available form may lead to Speckled Yellows of sugar beet, Grey Leaf of oats or an unhealthy condition of potatoes.

CONTROL MEASURES. On soils on which the trouble is known to occur it can be reduced by spraying the plants at flowering time with a weak solution of manganese sulphate, but farmers should always seek expert advice before attempting to correct any deficiency disease, otherwise more harm than good may result.

CHAPTER X

DISEASES OF CLOVER—CLOVER SICKNESS

"NOTWITHSTANDING all that has been said of the superiority of *lucern* to *clover*, and the excellence of *sainfoin* and various other leguminous plants, yet the red *clover* for mowing, and the white species for pasturage, are, and probably ever will be, found to excel all plants in these respects."[1] Whether or not modern agriculturalists would still endorse this view is a controversial question, but all would probably agree that the cultivation of clover becomes unprofitable when the land becomes "weary" of the crop, and the soil "clover-sick". As this "sickness" is the main cause of clover failures, a brief account is desirable of the views formerly held as to its cause.

Red clover was first introduced into English agriculture in the year 1645, by Sir Richard Weston, but it was not extensively cultivated until the eighteenth century. It was grown on the Continent, however, long before this time. The cultivation of white clover must have started at a later date for it is not mentioned by any of the English writers of the seventeenth century.

Although much was known of the valuable properties of clover centuries ago (Virgil in his Georgics described how it enriched the soil for the subsequent growth of corn crops) there are no early references to the peculiar "sickness" which attacks it. In the nineteenth century, however, especially towards the latter part, it was causing much comment and it is clear that it had then become a serious menace to successful cultivation. The keen minds of Lawes and Gilbert (1849 onwards) grappled with the problem, but, although they made many interesting field observations, they were unable to determine the primary cause. At this time, and for many years afterwards, the general opinion seems to have been that clover exhausted the soil of certain plant foods and when the supply of

[1] *The Book of the Farm*, by Henry Stephens. William Blackwood & Sons. 1844.

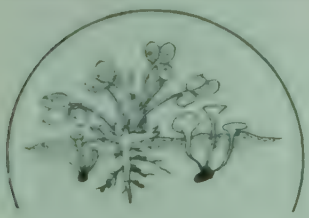
these failed the plants became "sick". "Marl, lime or chalk, is very congenial to Clover—containing much alkaline matter and lime; it will not flourish on land that has been exhausted of these substances, and which, consequently, becomes, in agricultural phrase, 'clover-sick'."[1] From about 1880 onwards, however, more detailed observations had made it clear that clover failures were usually associated with the presence, in the diseased tissues, of the fungus *Sclerotinia Trifoliorum*, or the Stem Eelworm, *Anguillulina dipsaci*. Many farmers, viewing with dismay a rotting field of clover, still believe the failure is due to a lack of some particular plant nutrient in the soil. It is true, of course, that clover failures may occur if soil conditions are unsuitable, and it is not adequately supplied with plant foods; but, even when the weather is all that can be desired, and the soil in a high state of fertility, clover may still fail and the land become "sick". If these failures are to be prevented in the future it is necessary to diagnose the condition accurately—is it due to the fungus *Sclerotinia Trifoliorum*, the Stem Eelworm *Anguillulina dipsaci*, or some other factor?

CLOVER ROT

Clover Rot, sometimes called Stem Rot, is caused by *Sclerotinia Trifoliorum*, and it is this fungus which so often contaminates the soil and makes it "sick". It occurs in most countries where clover is cultivated, and is known in Europe as well as in Great Britain. It is also prevalent in certain parts of the United States and Canada. In Britain it is widespread in East Anglia and in the chalk and limestone districts of Yorkshire (especially on the Wolds of the East Riding), Lincolnshire and the West Midlands: it is also found in the central Midlands, the southern and south-eastern counties, South Wales and the west country, but it is uncommon in Wales and the North, and rare in Devon and Cornwall. In this country official statistics of the estimated losses due to Stem Rot are not available, but in Germany it has been estimated that in the nine-year period 1928–36 the reduction in the clover

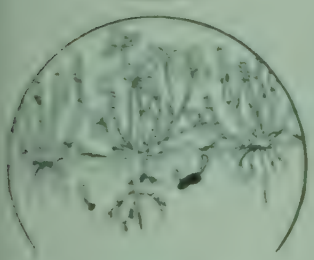
[1] *Sowerby's English Botany*: Edited by John Boswell Syme. Published by Robert Hardwicke, London. Vol 3, 1864.

Autumn - Winter - Early Spring



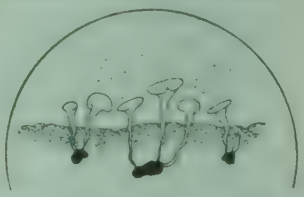
Spore-bearing bodies, *apothecia*, appear above the soil surface.

Autumn



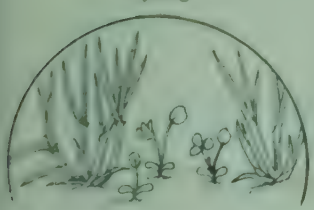
The sclerotia start to germinate.

Autumn - Winter - Early Spring



The *apothecia* produce spores which are shot into the air when they are ripe.

Spring

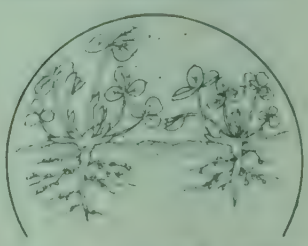


If clover or another susceptible crop is grown before the *sclerotia* are dead, disease may appear.

THE LIFE CYCLE OF *SCLEROTINIA TRIFOLIORUM* THE CLOVER ROT FUNGUS

Plan your rotations to prevent it.

Autumn - Winter - Early Spring



The wind blows spores on to healthy plants.

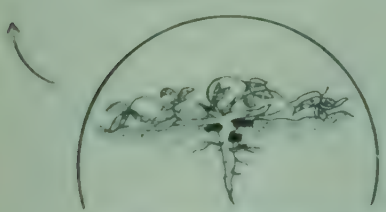
Late Summer - Early Autumn

The field is ploughed and the *sclerotia* are buried in the soil.

Autumn - Winter - Spring

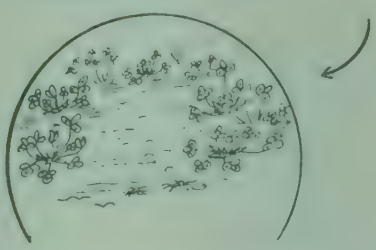
Clover rot develops on the infected plants.

Autumn - Winter - Spring



The fungus forms resting bodies on the dead plants; these *sclerotia* contaminate the soil.

Autumn - Winter - Spring



Gaps appear in the crop where plants have died.

FIG. 23. CLOVER ROT

crop due to this cause was some 40 per cent, a financial loss of about R.M. 47,000,000!

Symptoms and Life Cycle.—Clover Rot first appears in late autumn, often during October and November, but plants may become infected throughout the winter and early spring. The disease is most severe during a mild winter following a wet autumn, and in damp muggy weather it spreads rapidly leaving bare patches which are later colonized by weeds. The first sign of infection, which is not very well known because it normally escapes notice, is a "peppering" of the leaves and stems of affected plants with small, dark brown or black spots, but these must not be mistaken for Leaf Spot, a minor ailment caused by the fungus *Pseudopeziza Trifolii.* When the spotting is due to Clover Rot the foliage subsequently turns olive-brown, wilts and becomes covered with a white cobweb-like spawn which, in mild and damp weather, spreads along the ground and attacks adjacent plants. These are not always killed for, although the leaves become brown and rotten, the roots are not destroyed so quickly, and buds often break out at the crown and give rise to healthy shoots. Partial recoveries of this kind occur when dry, frosty conditions prevail, but the fungus may renew its activity in the summer and some of the stems may then wilt. During the spring, and to some extent during the latter part of the winter, sclerotia form on the dead and dying plants. These bodies are the same as those formed on beans affected with Bean Rot, and they have already been described (see page 66). Most of them develop on or near the stem bases and around the crown, but some may form at higher levels which account for their presence in carted hay; they may also form on the root several inches below the surface. It is these hard compact masses of spawn which, by contaminating the soil, make it "sick", and are responsible for subsequent attacks of Clover Rot. During the summer they remain dormant, but in early autumn those within an inch or so of the surface germinate and give rise to *apothecia*, and it is these which produce the spores which infect clover and related plants. Other sclerotia, more deeply buried in the soil, remain dormant for one or more years, but when cultivations

bring them near the surface they too may germinate and produce spores which are carried by the wind to nearby plants or neighbouring fields. It is not known with certainty for what period sclerotia may remain alive in the soil, but this will probably depend upon their depth below the surface, soil moisture and other variable conditions. It is thought, however, that some may survive for six or seven years, but experience has shown that, on land where Clover Rot has been troublesome, it is usually safe to resow red clover after an interval of eight years.

Varying Susceptibility of Plants to Clover Rot.—Clover and allied plants vary considerably in their susceptibility to the disease. Common or broad red clover suffers more frequently and severely than any other variety, but late-flowering clover (single-cut cowgrass) is also very susceptible. Trefoil, although often affected, and more so than is generally realized, usually withstands the disease better, and the attack is generally less intense. Alsike and white clover are occasionally attacked but not severely and wild white is reputed to be immune or nearly so. Lucerne is subject to attack in its first year, especially if late-sown; but it shows increasing resistance after one season's growth and crops which have stood the first winter are seldom affected in succeeding years. Sainfoin is moderately resistant in its first year, and, as with lucerne, when once established shows increasing resistance. Vetches or tares are very rarely attacked in this country and the disease has not yet been observed on field peas. It is otherwise, however, with field beans for they sometimes suffer severely from Bean Rot—a disease caused by the same fungus and described in a previous chapter (Chapter VIII).

CONTROL MEASURES. The remedy for clover and bean "sickness" is to starve the fungus in the soil by growing only those crops that are resistant or less susceptible to the disease. On land where Clover Rot has been troublesome, an interval of eight years should be allowed before common red clover and late-flowering red clover are taken again. During this period, sainfoin or lucerne can be sown if there is sufficient chalk in the soil, or alsike or

white clover may be substituted, either alone or with Italian ryegrass. Winter beans should not be grown, but spring-sown beans are seldom attacked. Peas may be taken as they too escape the disease. When a return is made to red clover, however, it is advisable to sow it with Italian ryegrass or with alsike and trefoil.

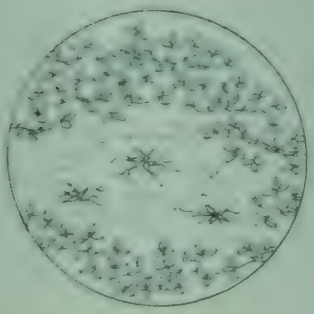
On land known to be liable to Clover Rot an adequate supply of lime, potash and phosphates should be given, and heavy dressings of organic and nitrogenous manures avoided. The object should be to encourage robust plants, and not luscious growth. On rich land where a luxuriant growth is produced in the autumn, grazing by sheep in September and October is sometimes beneficial. It is a practice to be carried out with discretion, however, for grazing of red clover by sheep is not general practice, and, on poor thin land, it may well result in a substantial reduction of the stand. As an alternative to grazing the crop may be cut with the grass mower and made into silage.

STEM EELWORM

Clover failures are not always due to Clover Rot and sometimes "sickness" arises from an entirely different cause—the presence in the soil of the Stem Eelworm *Anguillulina dipsaci*. This is not the same strain which infests potatoes, and, as far as is known at present, the only crops susceptible to it are clovers and certain closely related plants. As the susceptibility of weeds has not been fully investigated, however, it is possible that some of these too may harbour the disease.

Symptoms.—Unlike Clover Rot, which is usually distributed more or less regularly over the field and its rate of spread conditioned by the weather, an Eelworm attack starts from a central point, or points, and spreads slowly and steadily in an ever-widening circle. The symptoms of Stem Eelworm in red clover are usually first noted in the autumn when patches of plants lose their vigour and become stunted and sickly-looking. A more careful examination then shows that the bases of the shoots are swollen and puffy or spongy in texture. The leaves are somewhat lighter in colour, and the leaf-stalks often distorted. There may be numerous short side-shoots, and these give

1



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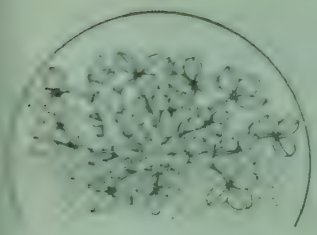
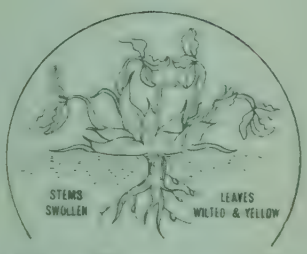


Soil becomes contaminated and plants infested.

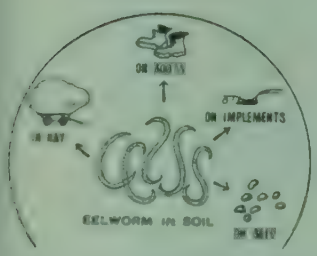
In Autumn circular patches of dead and sickly-looking plants sometimes appear in the clover crop (1). Affected plants are stunted with swollen stem bases and distorted leaf-stalks, owing to the presence within them of minute eelworm (2 and 3). When these plants die some eelworm escape into the soil, but others remain in the dead plants (4). As this pest is able to withstand prolonged drying, it can be carried in soil adhering to boots or implements, or even in hay (5), and in this way clean fields become contaminated (6).

2



Clover Plant attacked by eelworm.

5



Eelworm carried to clean land.

3

Eelworm and eggs in swollen stems.

4

Infected plant dies and eelworm migrate into the soil.

FIG. 24. CLOVER STEM EELWORM

the plants a tufted appearance. The roots are not attacked, and it is not until the leaves start to die that a gradual decay sets in, and bare patches appear in the crop. It is not possible by the unaided eye to detect the eelworms in infested plants, but they are readily seen if some of the affected tissue is scraped away, mounted in a drop of water, and examined under the microscope.

Life Cycle.—The adult eelworm lays eggs inside the clover stems. These hatch and the young worms feed on the tissues. Whilst the plant is alive and there is ample food, breeding is continuous, but when the plant dies the eelworms either enter the soil in search of fresh plants on which to feed or stay in the dead tissue where they can remain in a dried-up condition for a long period. Subsequent infection, therefore, may arise from infested soil or infected hay.

CONTROL MEASURES. As no satisfactory chemical treatment has yet been discovered which will destroy Eelworm in the soil, the pest must be starved from it. This may take at least three or four years, during which period susceptible crops must not be grown. The relative susceptibility of clover and closely allied plants to the various races or strains of Stem Eelworm is not yet fully known and is still the subject of research, but on fields on which Clover Eelworm has appeared it is usually safe to plant peas, beans, vetches (except kidney vetch) and sainfoin. It is advisable to keep the land as free as possible from weeds and "volunteer" plants, in case some of these are able to harbour the parasite and enable it to carry over from season to season.

Robust growth should be encouraged, but this must not be forced by too liberal dressings of nitrogenous manures otherwise the plants may be made more susceptible to the Clover Rot fungus.

Clover Rot and Stem Eelworm are the two important diseases of clover, but there are several minor ailments. Fortunately they cause little loss in normal seasons, and brief mention only is made of them here. There are two mildew diseases, Powdery Mildew and Downy Mildew.

Powdery Mildew (*Erysiphe Polygoni*) is the more prevalent and covers the plants with a fine white weft of spawn; it is usually more noticeable on the aftermath than it is on the main hay crop, but it is doubtful if it is responsible for any appreciable loss. Red and crimson clover appear to suffer most, but severe attacks also occur on sainfoin. It is favoured more by dry conditions than wet weather.

Downy Mildew (*Peronospora Trifoliorum*).—This disease is often noticeable on lucerne, but it also occurs on various clovers and trefoil. Another species, *Peronospora Viciae*, attacks vetches. Downy Mildew appears on the under-surface of the leaves as a rather mealy, light violet-grey weft of spawn. After a while the leaves and stems lose their fresh green colour and become sickly-looking. Downy Mildew does not spread as rapidly as Powdery Mildew but affected plants are more severely checked. The disease is of minor importance in Britain and no control measures are practised.

Leaf Spotting.—Apart from the "peppering" of the foliage which initiates a Clover Rot attack, brown or brownish-black spots may be caused by one of several different fungi. The most common of these is *Leaf Spot* caused by the fungus *Pseudopeziza Trifolii*, and a very similar fungus, *Pseudopeziza Medicaginis*, marks the leaves of lucerne and trefoil. The spots are brownish-black in colour but later develop a lighter centre; they vary in size from small pin points to dots about one-tenth of an inch in diameter. In some seasons these sooty leaves are very noticeable, but the disease is of little economic importance and no control measures are practised.

Various other forms of leaf spotting occur on clovers, trefoil, vetches, sainfoin and lucerne, but, to avoid confusion, and as they seldom cause any very severe loss, a description of them is omitted and the student is referred to *Diseases of British Grasses and Herbage Legumes*[1] for further information.

Crown Wart of Lucerne.—This disease is due to *Urophlyctis Alfalfae*. It is rather rare in this country but it

[1] *Diseases of British Grasses and Herbage Legumes*, by Kathleen Sampson and J. H. Western, Cambridge University Press, 1941.

is liable to occur where land is badly drained, or when flooding has taken place. The visible symptoms in the field are wilting and yellowing of the stems, but if affected plants are carefully removed and examined, irregular warty galls will be found on the crown at or about soil level.

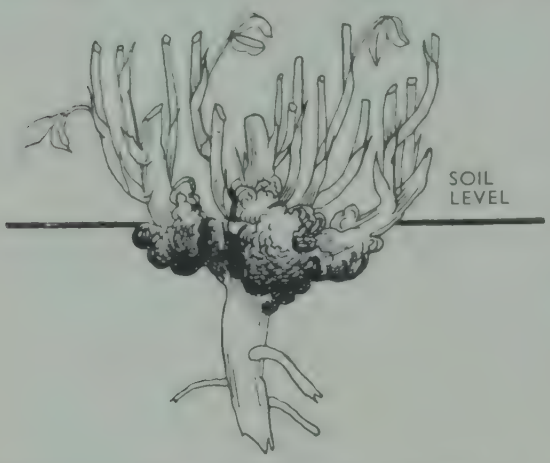


FIG. 25. CROWN WART OF LUCERNE
(*Urophlyctis alfalfae*)

To prevent the recurrence of Crown Wart on contaminated soil, drainage should be improved, and lucerne should not be grown for four or five years.

Black Stem of Lucerne.— Until recently little was known about this disease, but it appears to be widely distributed in Britain. It is caused by the fungus *Ascochyta imperfecta* and can be recognized by brownish-black markings, an inch or so in length, on the stems and leaf-stalks. Spots of variable size and shape also occur on the leaves. When the attack is severe the fungus penetrates deeply into the tissues, cankers develop and the shoots wilt. These symptoms are most noticeable in spring or early summer, and it is at this time that most injury is caused.

FIG. 26. BLACK STEM OF LUCERNE
(*Ascochyta imperfecta*)

Life Cycle.—The fungus overwinters in dead lucerne shoots and from these infection of new shoots arises in the spring.

CONTROL MEASURES. The first crop of herbage should be cut early in the spring before leaf and stem injury is severe. When this is done later cuttings are not so severely affected.

Before concluding this short account of clover diseases, it is necessary to mention one other form of parasitism to which both clover and lucerne are susceptible—Dodder.

Dodder (*Cuscuta Trifolii*).—Dodder is a parasitic flowering plant without leaves, green colouring matter, or proper root system. As it is unable to utilize the carbon dioxide of the air and the salts of the soil to make its own food supplies, it steals these in a ready-made form from clover plants. It does this by twining around them and sending suckers (*haustoria*) into the stems, from which it absorbs the plant juices. The seeds of dodder are very small, and at one time they were a common impurity of clover seed samples. During the past thirty or forty years, however, there has been a progressive decrease in the number of commercial seeds samples contaminated by dodder seeds, and consequently it is now uncommon to find clover or lucerne crops affected by this curious parasite.

FIG. 27. DODDER
(*Cuscuta Trifolii*)

Life Cycle.—As the dodder seed germinates a thread-like coil unwinds and one end enters into the soil, whilst the other part lengthens into a stem devoid of leaves. When it reaches a clover

plant it twists around this and attaches itself by means of suckers. When firmly established and its food supply secured, it ceases to have any contact with the soil, and its stems, branching out, entangle other clover plants. It then produces compact clusters of white bell-shaped flowers which form tiny seeds. How small these are can be gathered when it is said that one pound of clover seed, with but 1 per cent by weight of European Clover Dodder seeds as an impurity, would contain about 18,000 dodder seeds. To prevent the introduction of dodder into clover leys it is clear, therefore, that every possible precaution must be taken.

CONTROL MEASURES. If seed samples are free from dodder, the parasite will not appear on the farm. One of the clauses of the Seeds Act, 1920, requires all sellers of clover or grass seed to declare dodder in seed samples if it is present to the extent of more than one seed in four ounces of red clover, crimson clover, or lucerne, or in two ounces of alsike clover, white clover or timothy, or in one ounce of wild white clover. It is always a wise precaution to make quite sure that dodder seed is not present in clover seed samples. This can be done by submitting samples to the Official Seed Testing Station, Cambridge. A summary of the requirements of the Seeds Act and Regulations, together with full particulars of the fees charged by the Seed Testing Station and instructions for sending samples, may be obtained from the Ministry of Agriculture and Fisheries, London.

If small patches of dodder are found infesting a crop, these should be destroyed at once. This can be done by burning with straw. The affected plants should not be removed and then destroyed, as small pieces may be dropped and this may spread it farther afield.

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